Mestrado em Eng Electrotécnica e Computadores

RADIOPROPAGAÇÃO

Radio Wave Propagation

Mobile radio communications

Carlos A. Cardoso Fernandes

1. Introduction

1.1 Mobile communications

1. Introduction

1.2 Mobile radio services

Satellite coverage

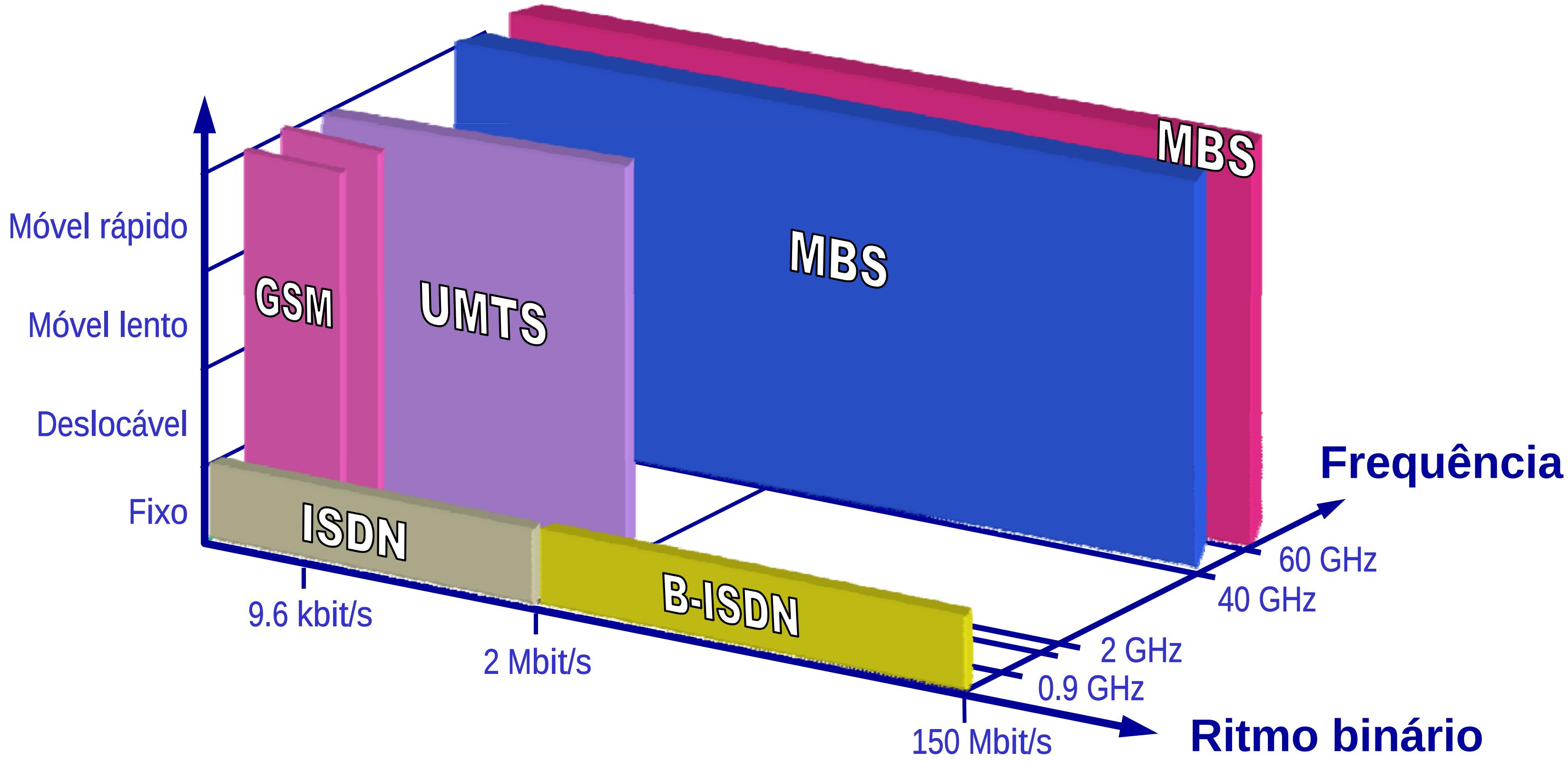
- Aeronautical Mobile Satellite Services (AMSS)
- Maritime Mobile Satellite Services (MMSS)
- Land Mobile Satellite Services (LMSS)

Land mobile coverage

- GSM
- UMTS
- WI-FI, WIMAX
- HIPERLAN
- MBS

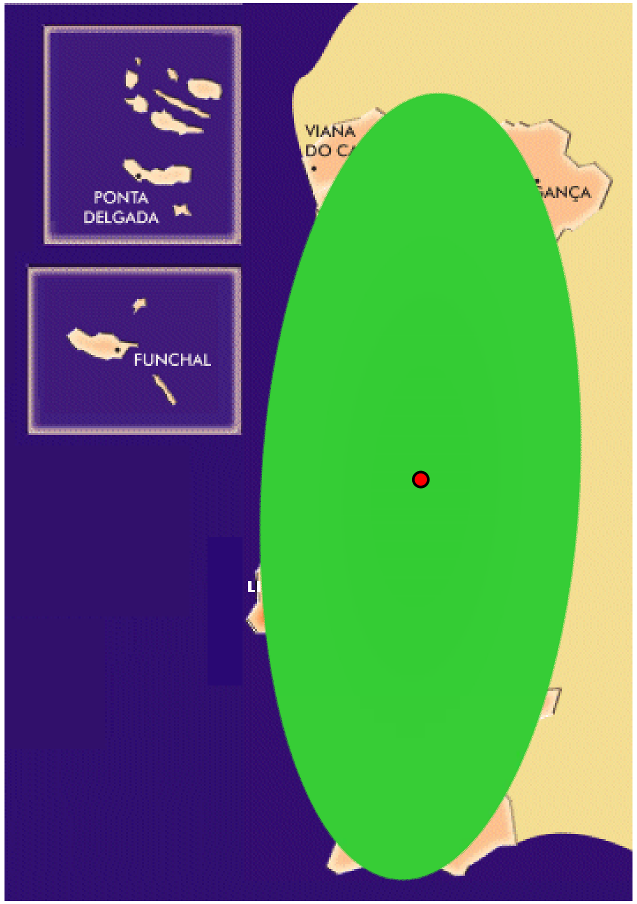
1. Introduction

1.3 Land mobile services



1. Introduction

1.4 Global coverage vs cellular coverage



1. Introduction

1.5 Propagation modes

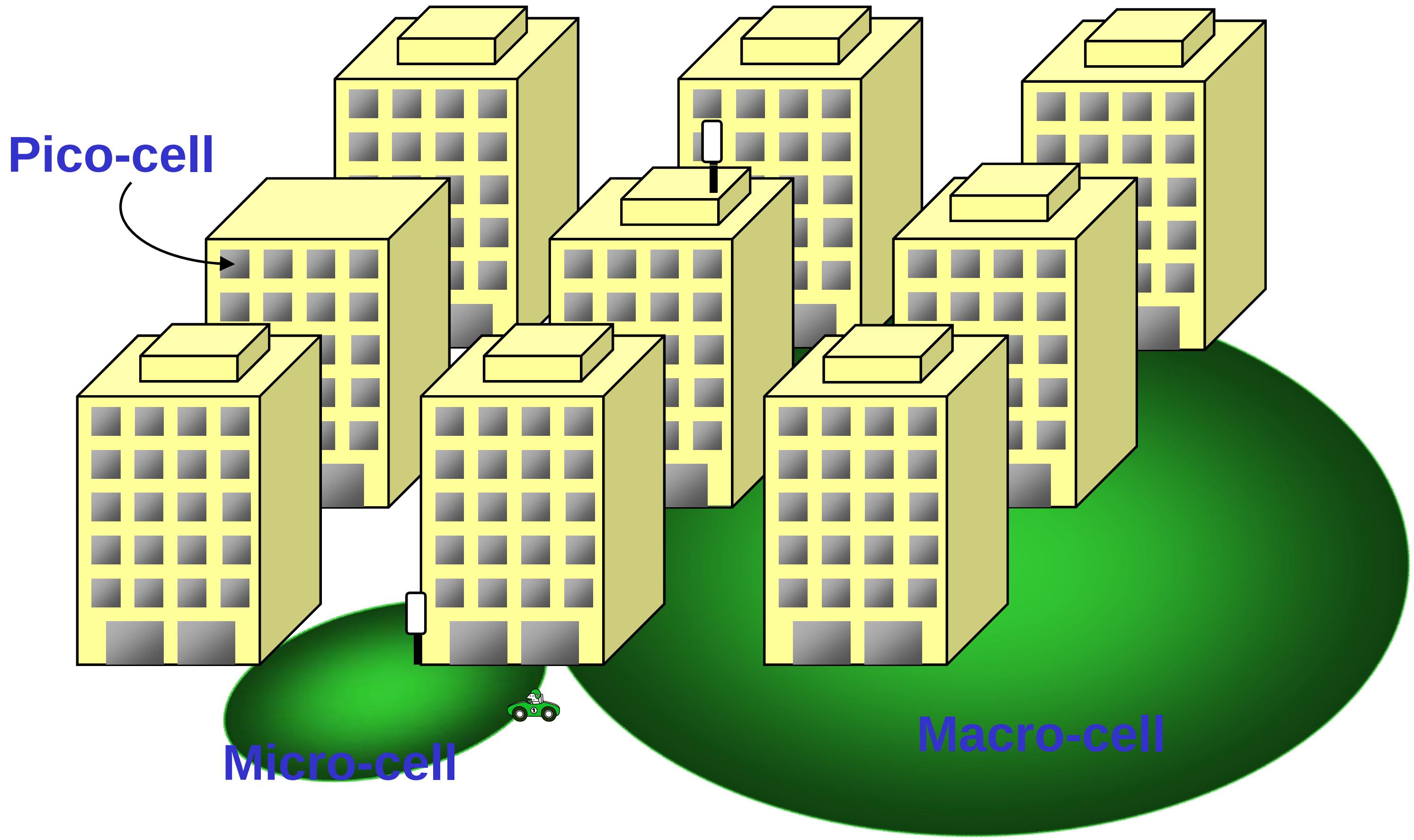
Cellular coverage requires accurate prediction of received signal level

• Deterministic models

• Statistical models

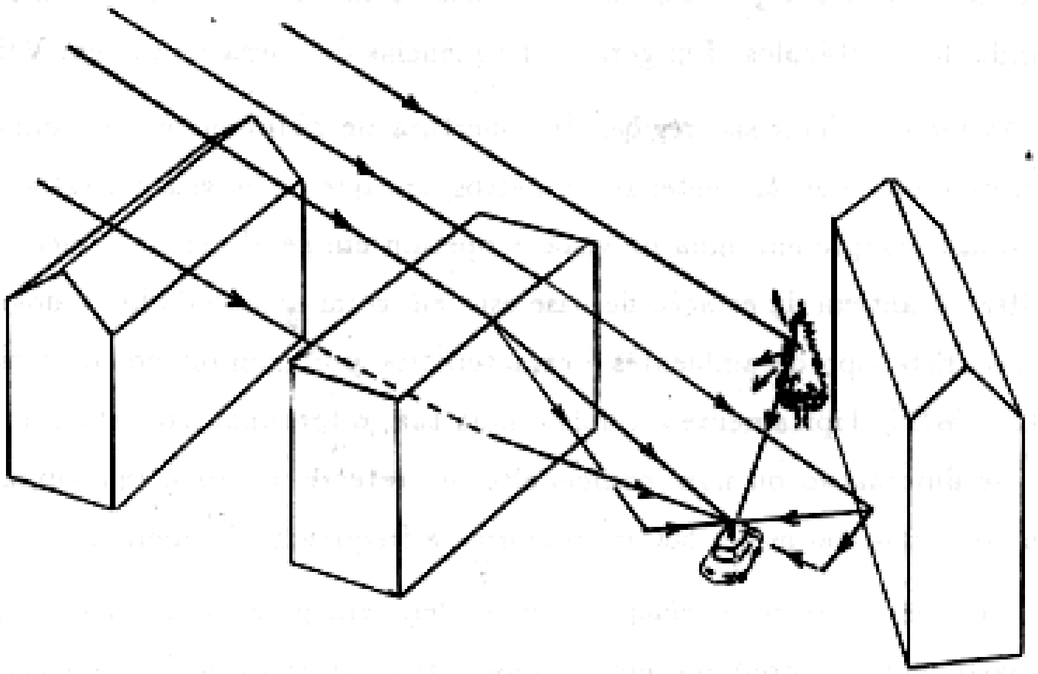
• Integrated models (estat. + determin.)

2. Scenarios for land mobile communications



3. Specifics of land mobile scenarios

Propagation over roof-tops followed by diffraction down to street level (shadowing + multipath)

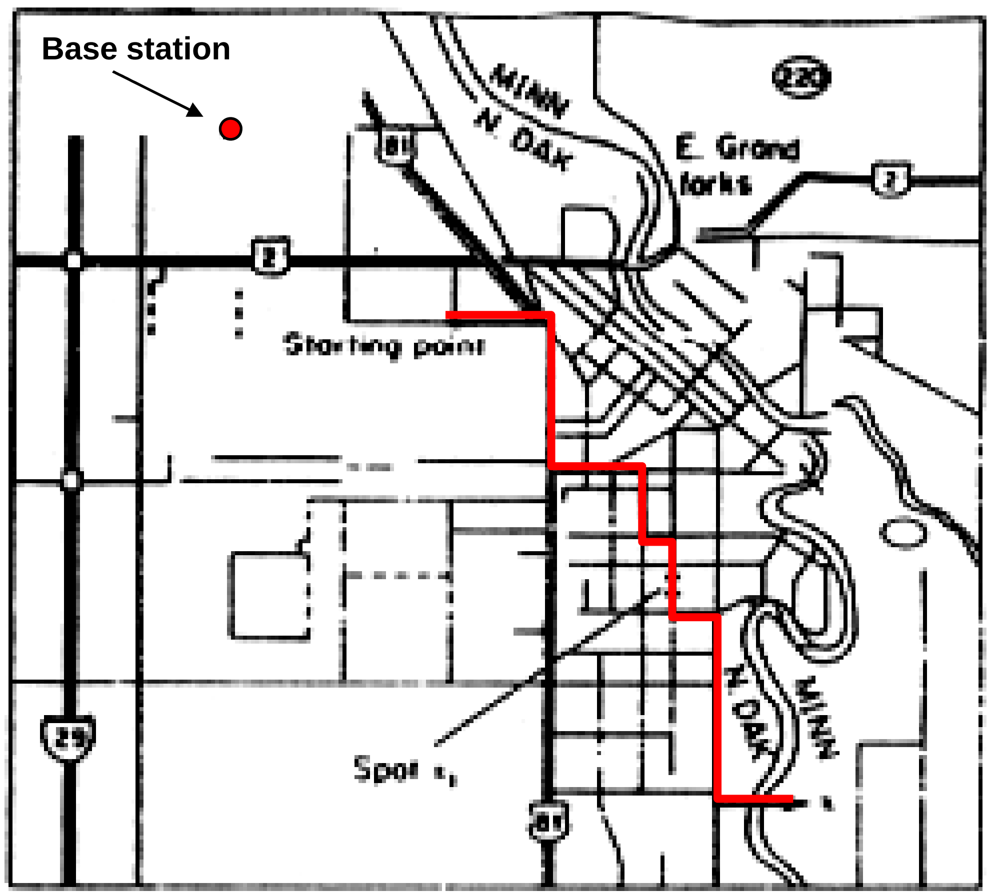


3. Specifics of land mobile scenarios

Effective scattering region slides centered with the mobile (~30 λ radius)

3. Specifics of land mobile scenarios

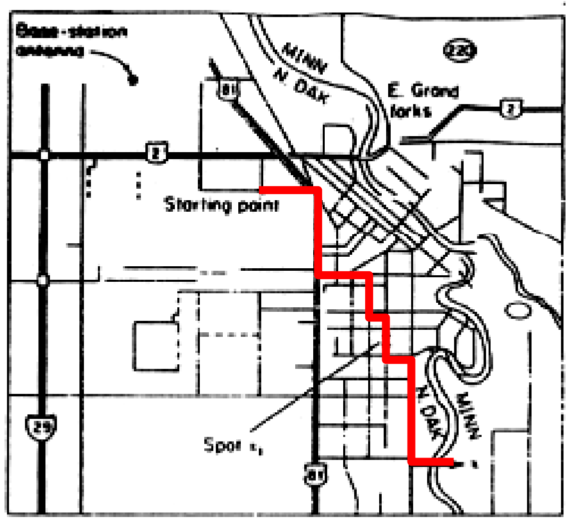
Typical urban location



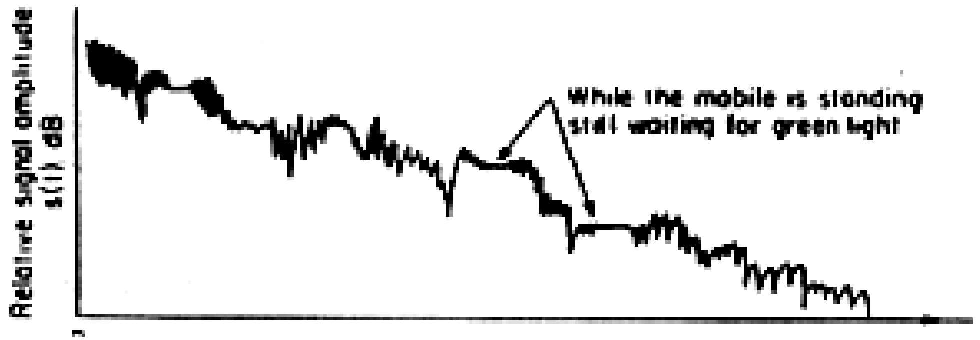
(a)

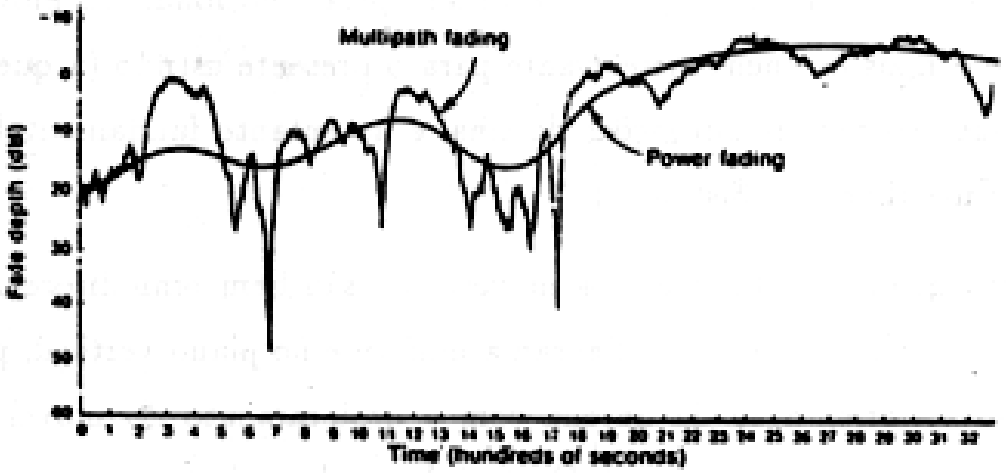
3. Specifics of land mobile scenarios

Different scales of signal level variation with distance



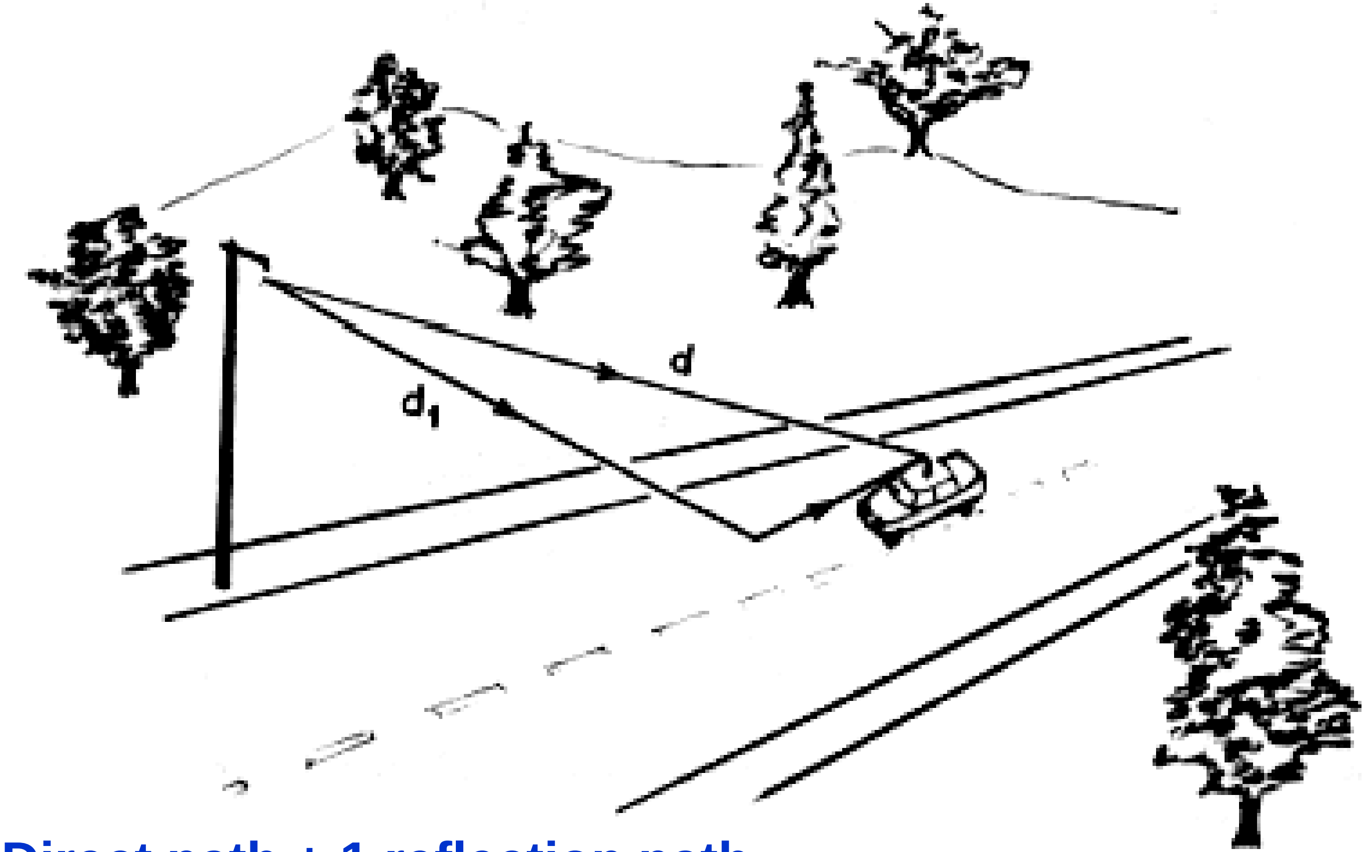
(a)





4. Rural micro-cell

4.1 Typical scenario



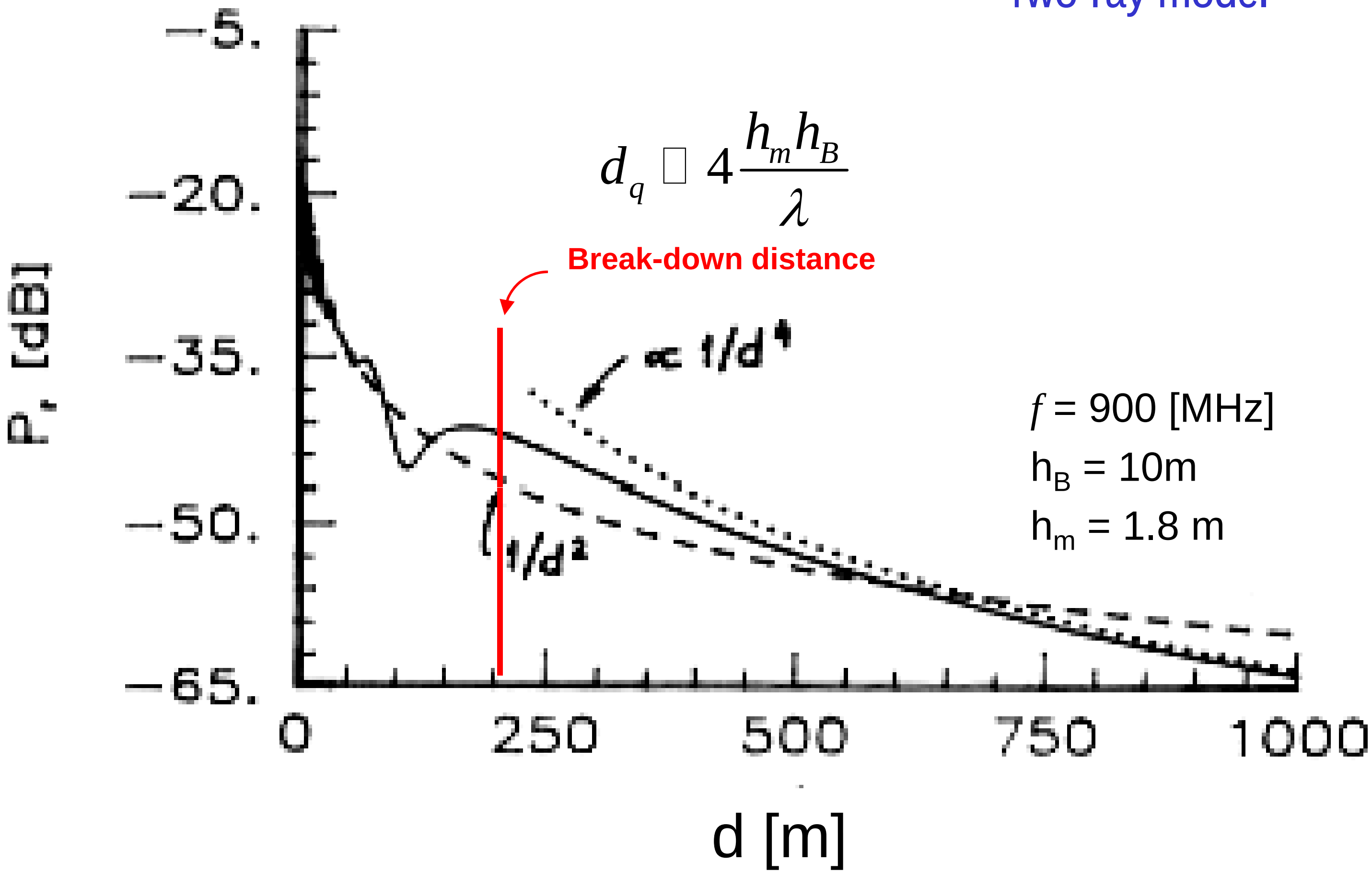
Direct path + 1 reflection path

4. Rural micro-cell

4.2 Break-down distance

Two-ray model

$$d_q \approx 4\frac{h_m h_B}{\lambda}$$

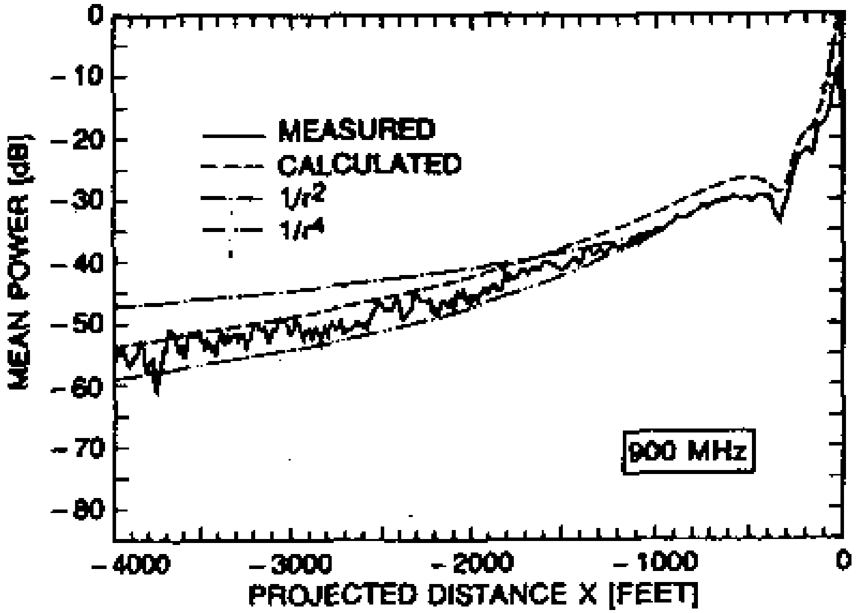


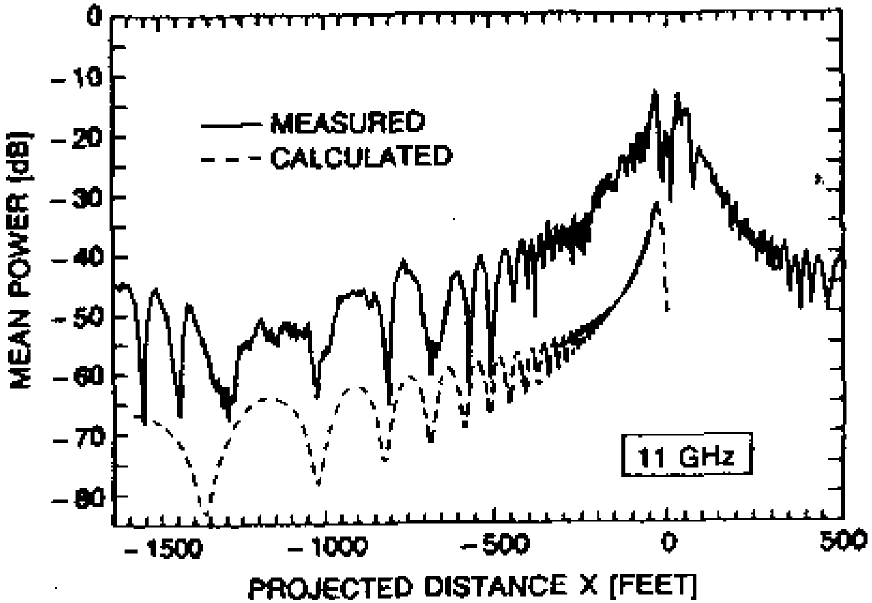
f = 900 [MHz]
h_B = 10m
h_m = 1.8 m

4. Rural micro-cell

4.3 Comparison with experimental results

Two-ray model



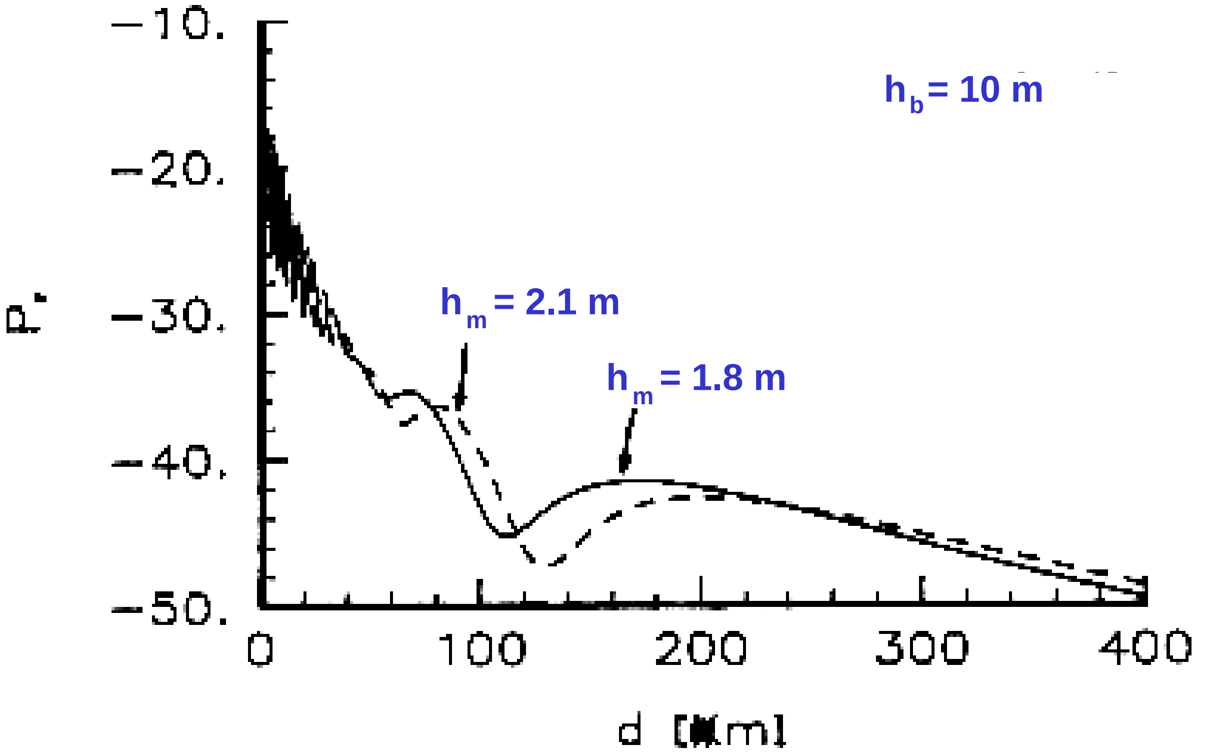


- 1200 [m] - 900 [m] - 600 [m] - 300 [m] - 300 [m] - 150 [m] 150 [m]

4. Rural micro-cell

4.4 Effect of antenna height variation

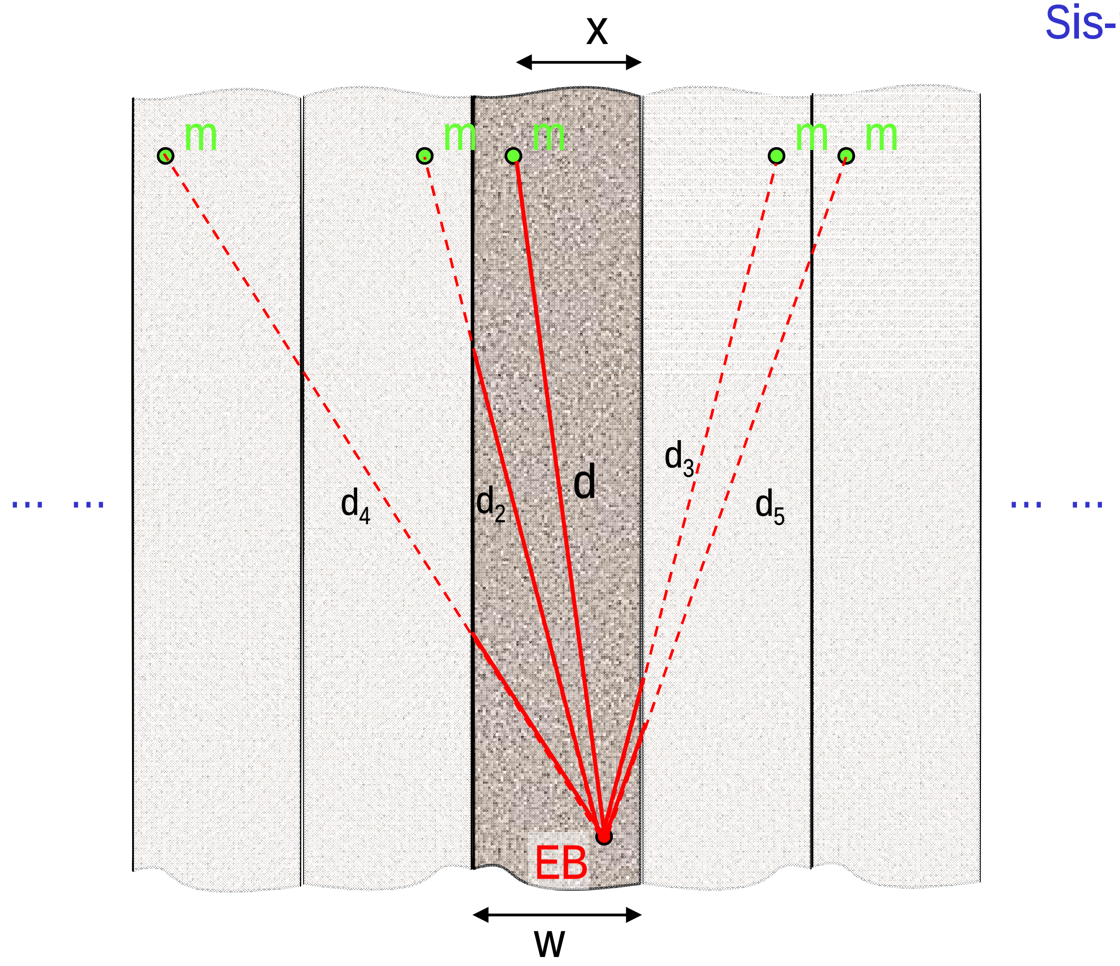
Two-ray model



5. Urban micro-cell

5.1 Dielectric canyon

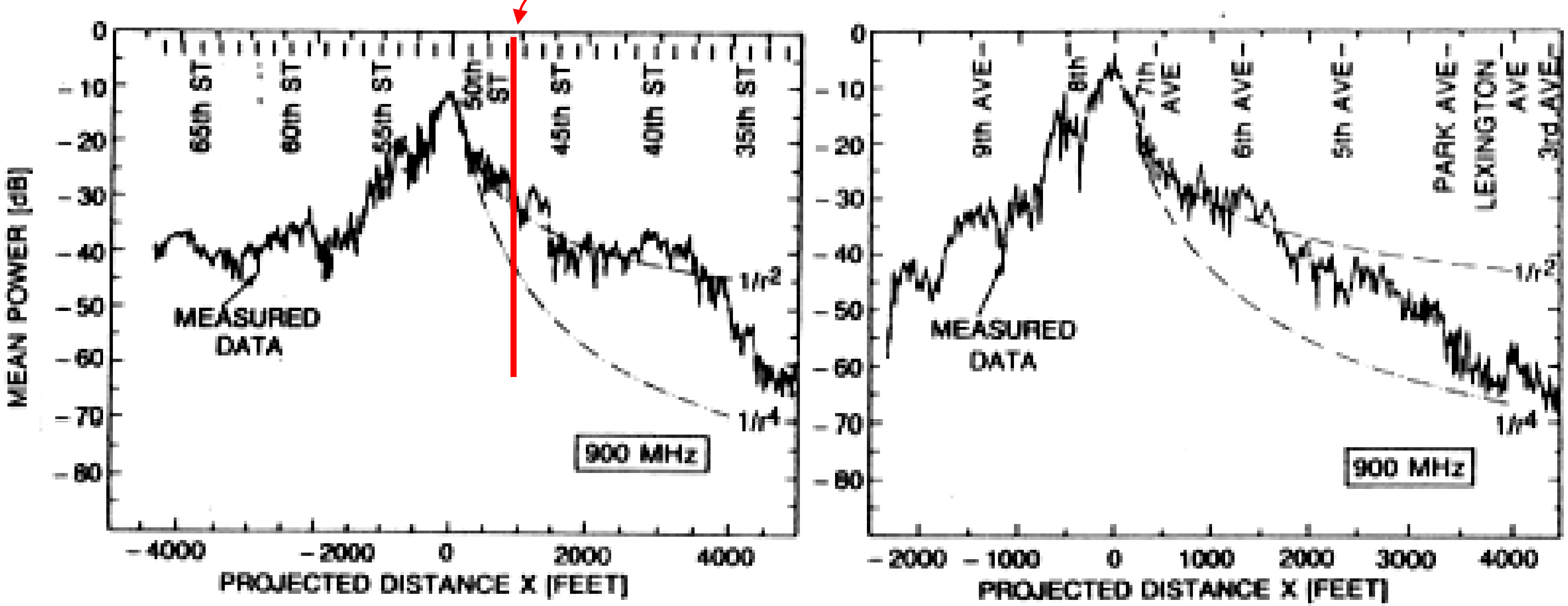
Sis-ray model



5. Urban micro-cell

5.2 Comparison with experimental results

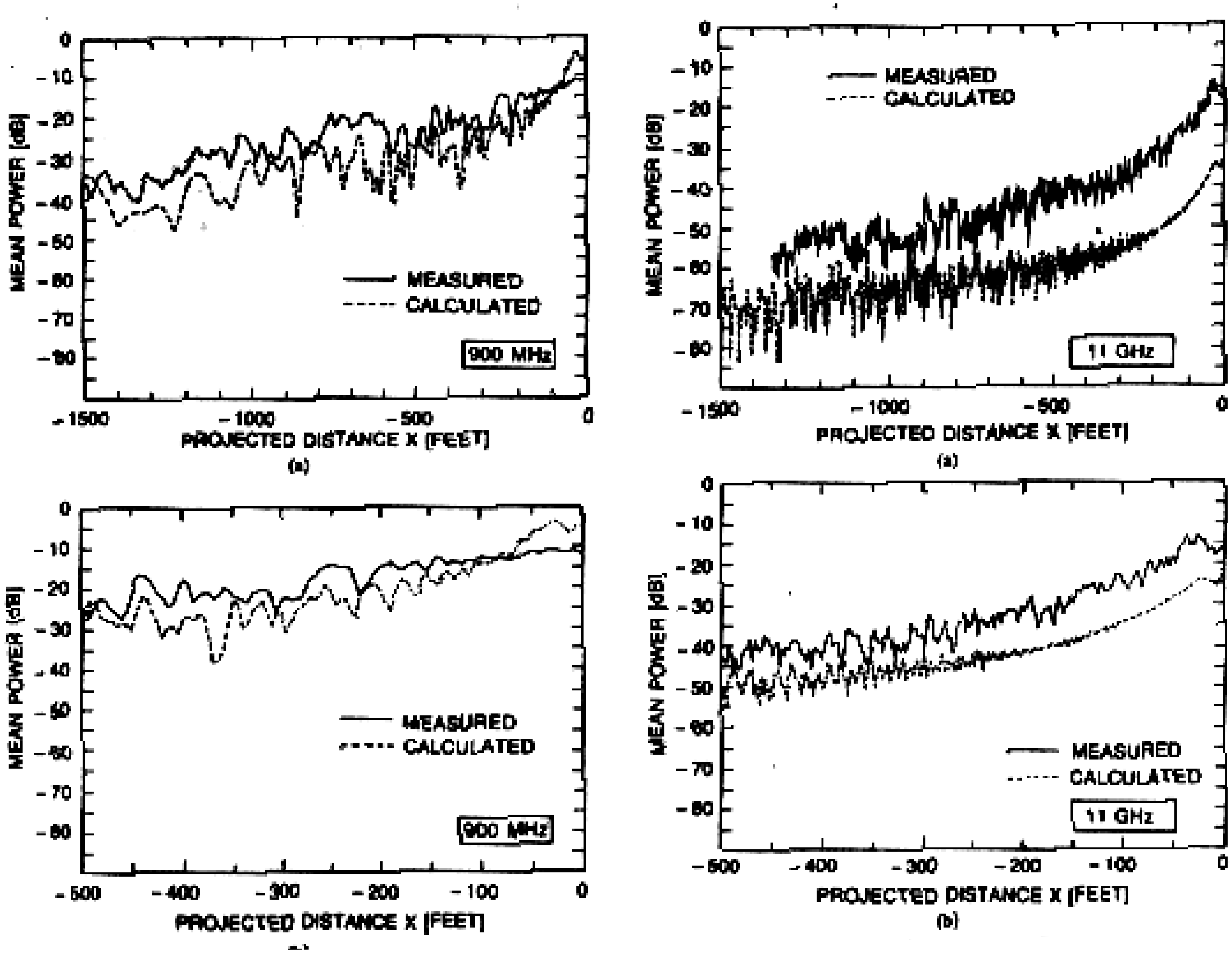
No beak-down !!



-1200 [m] - 600 [m] 0 600 [m] 1200 [m] - 600 [m] 0 600 [m] 1200 [m]

5. Micro-célula urbana

5.2 Comparison with experimental results



Six-ray model

6. Micro-cells at mm-waves

6.1 Introduction

Applications

- Broadband mobile communications (40 or 60 GHz)
- Gigabit wireless networks (WirelessHD)

Why 60 GHz

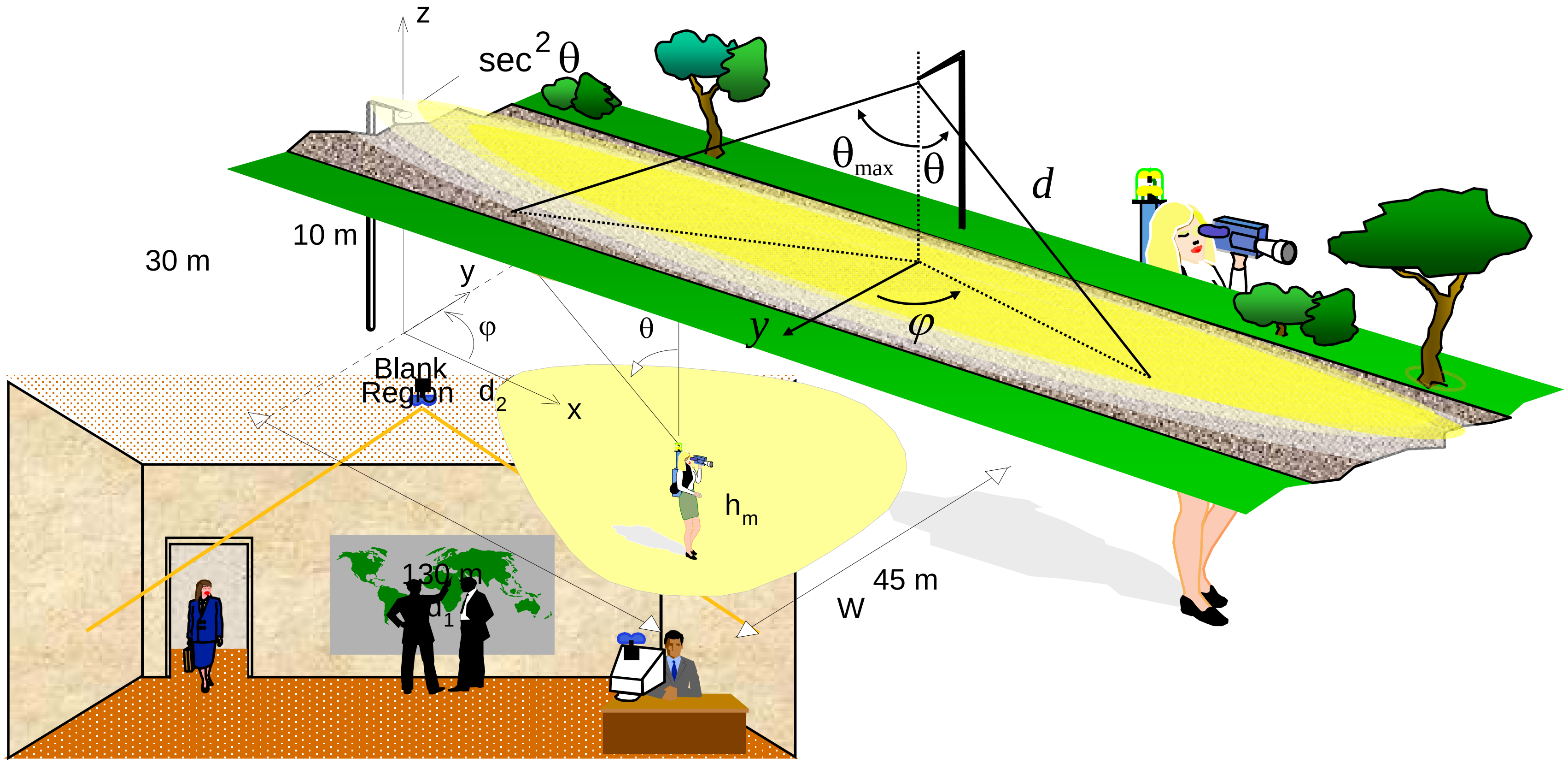
- Oxygen absorption (~15 dB/km)
- Spectrum availability, emerging affordable technology

Implications

- Small frequency reuse distances
- Effective EM energy confinement to the cell
- Ray models even more adequate
- Surface roughness may play a role
- Rain can be an issue (for outdoor applications)

6. Micro-cells at mm-waves

6.2 Possible scenarios

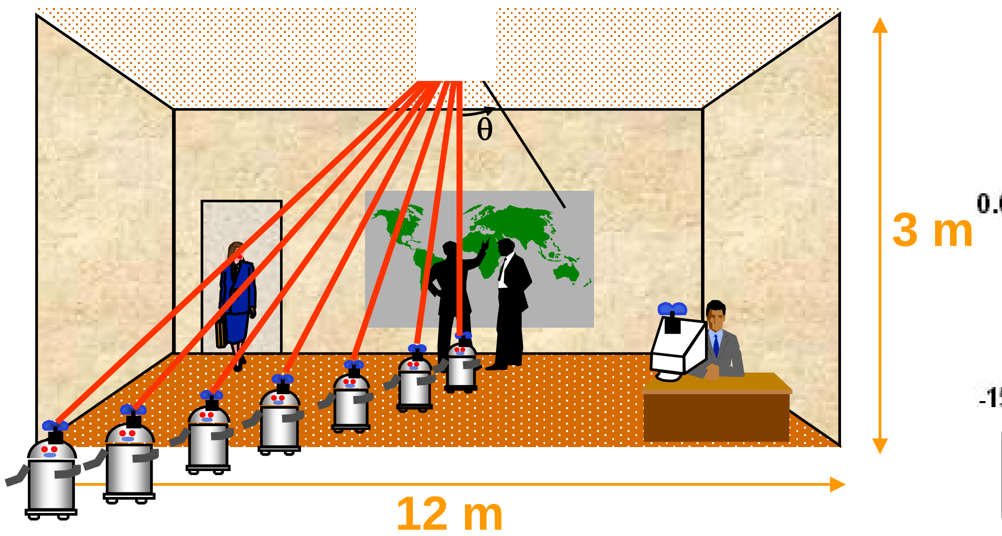


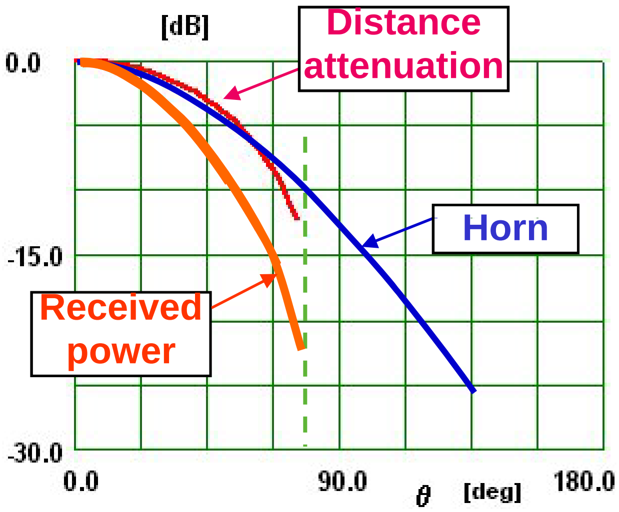
Typical cell range: 6 to 300 m

6. Micro-cells at mm-waves

6.3 Importance of antennas

$$P_r = P_e \frac{\lambda^2}{(4\pi)^2} \frac{G_r \; G_e(\theta,\varphi)}{d^2}$$

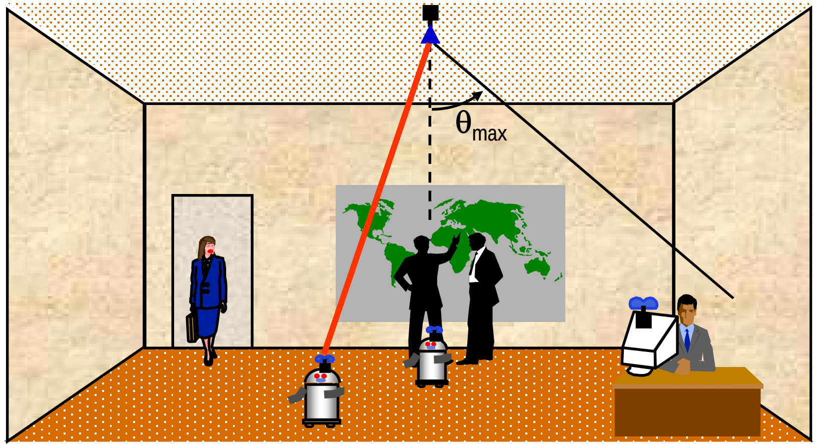




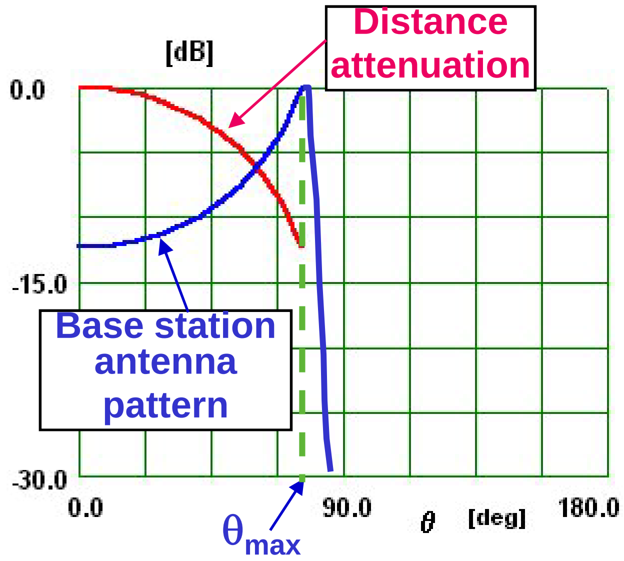
High received power dynamic range

6. Micro-cells at mm-waves

6.3 Cosecant square antennas



$$P_r = P_e \frac{\lambda^2}{(4\pi)^2} \frac{G_r \; G_e(\theta,\varphi)}{d^2}$$



- **Constant received power within the cell;**

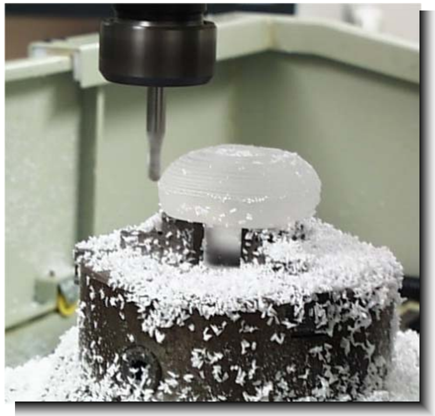
$$G_e = \sec^2 \theta = d^2 / h^2$$

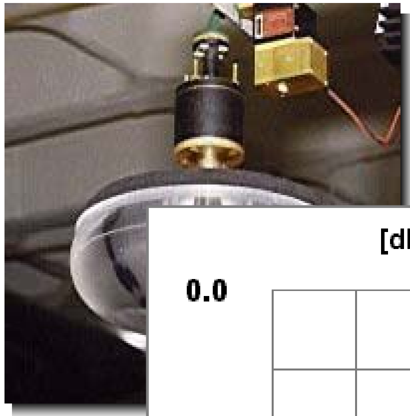
- **Controlled reflection from walls;**

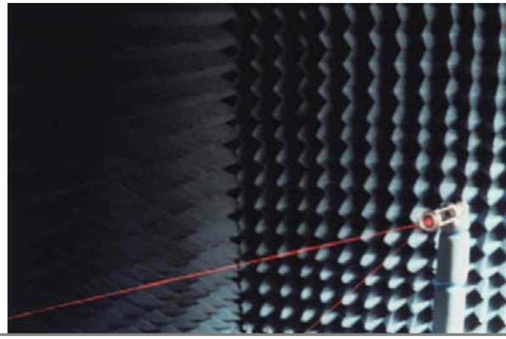
6. Micro-cells at mm-waves

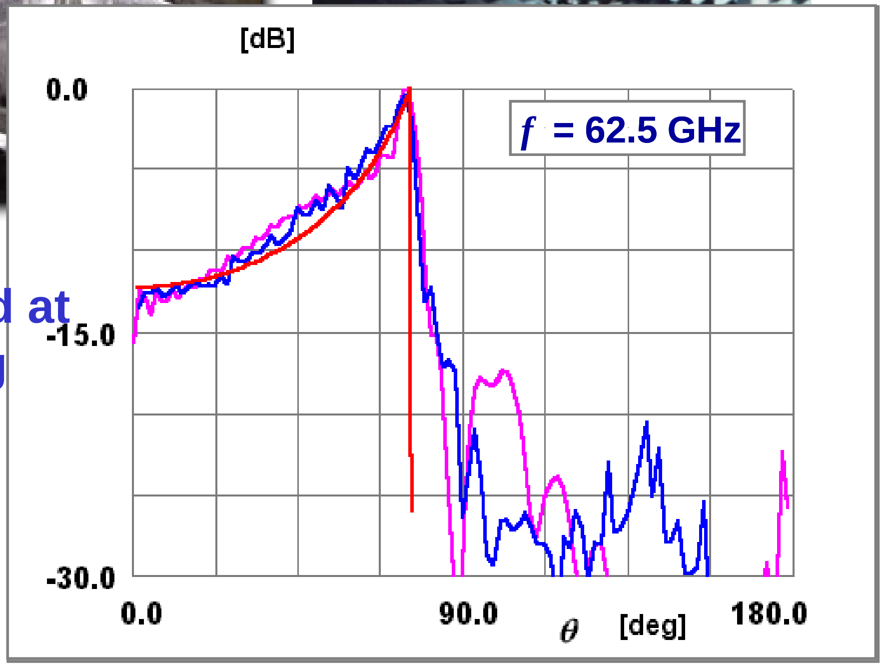
6.4 Antenna examples

New concept developed at IST







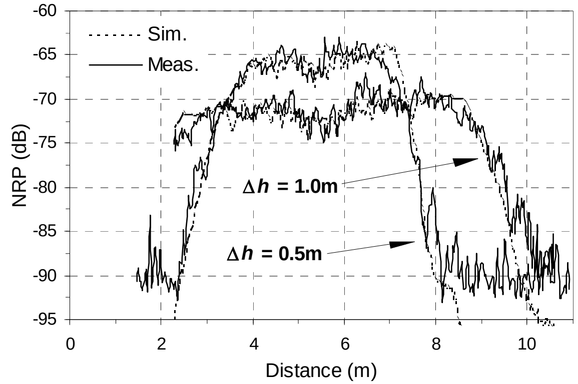


Lenses can be produced at low-cost by moulding

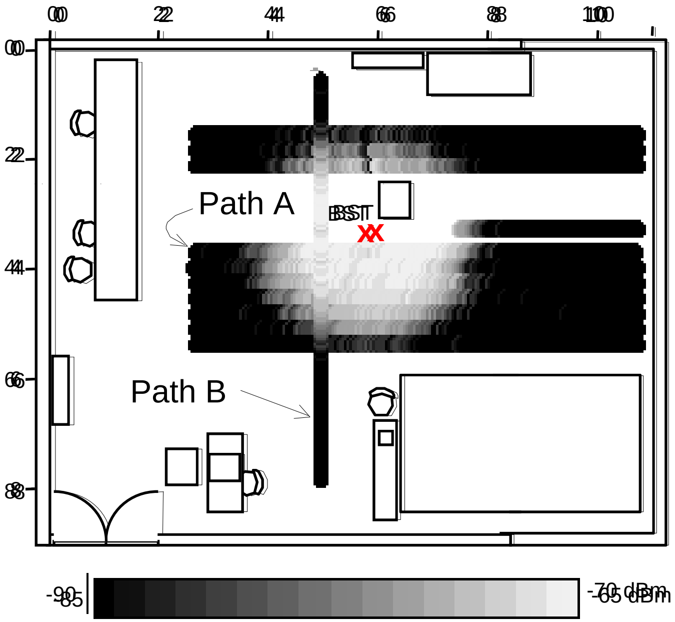
- Target
- Measured
- Simulation

6. Micro-cells at mm-waves

6.5 Typical coverage of these antennas



f = 62.5 GHz



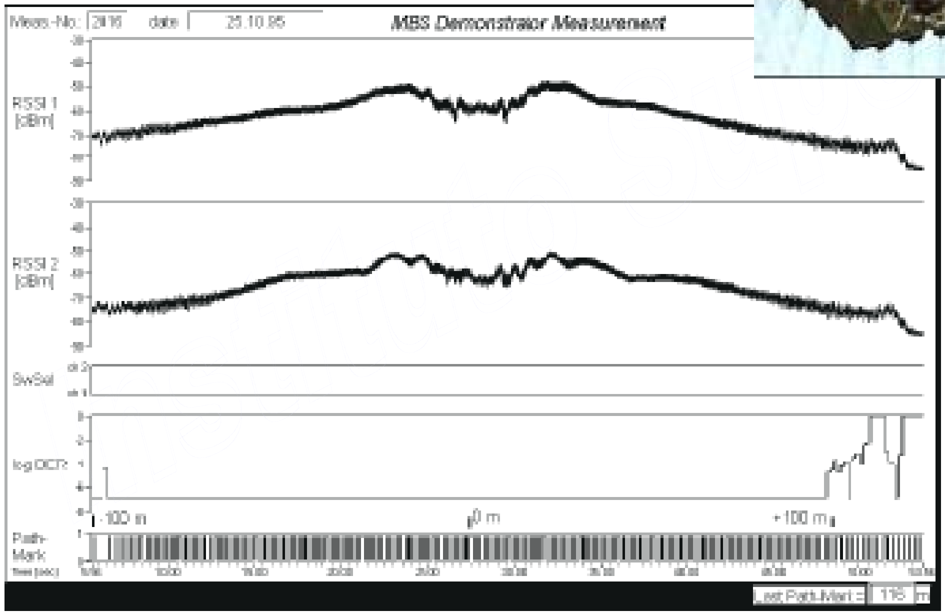
- Cell edge is very sharp.
- Cell radius is proportional to antenna height.

6. Micro-cells at mm-waves

6.6 MBS project

(Mobile Broadband Systems)

Cosecant square antennas developed at IST



Public demonstration, ULM Germany, 1996

6. Micro-cells at mm-waves

6.6 SAMBA project

System for Advanced Mobile Broadband Applications

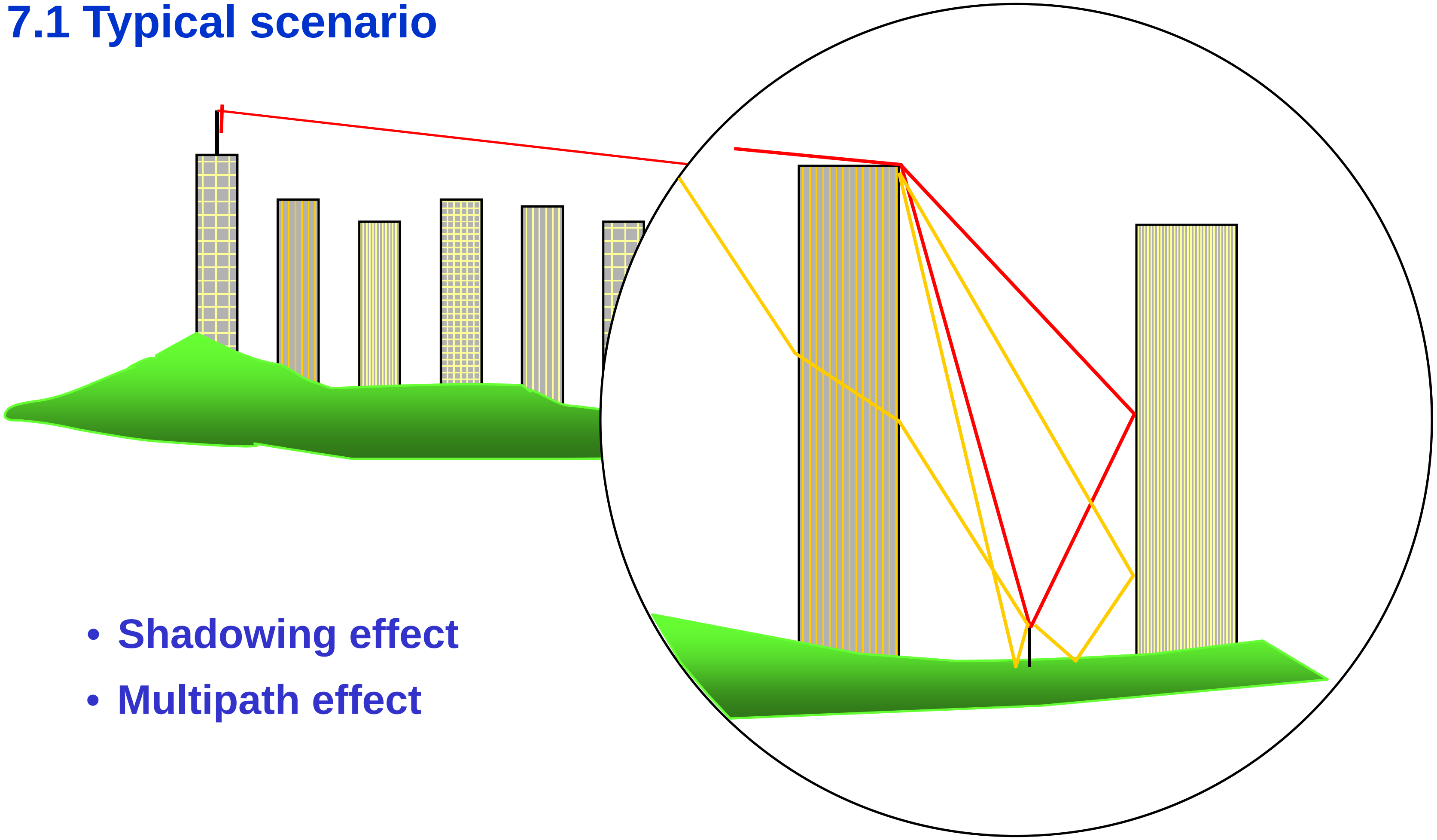
Cosecant square antennas developed at IST

Public demonstration at Utopia Pavillion, EXPO 98, Lisboa

(Pavilhão Atlântico)

7. Macro-cells

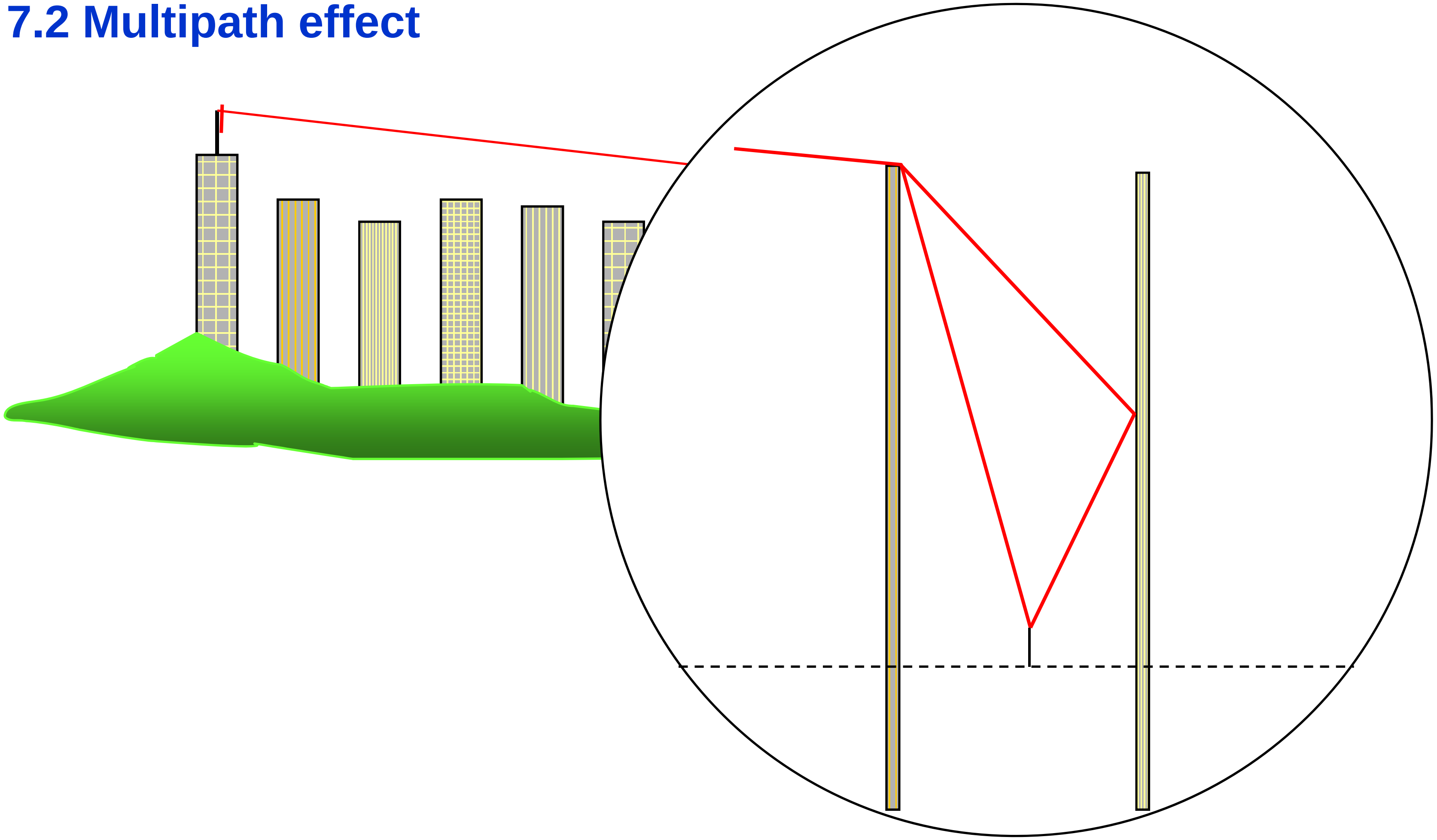
7.1 Typical scenario



- **Shadowing effect**
- **Multipath effect**

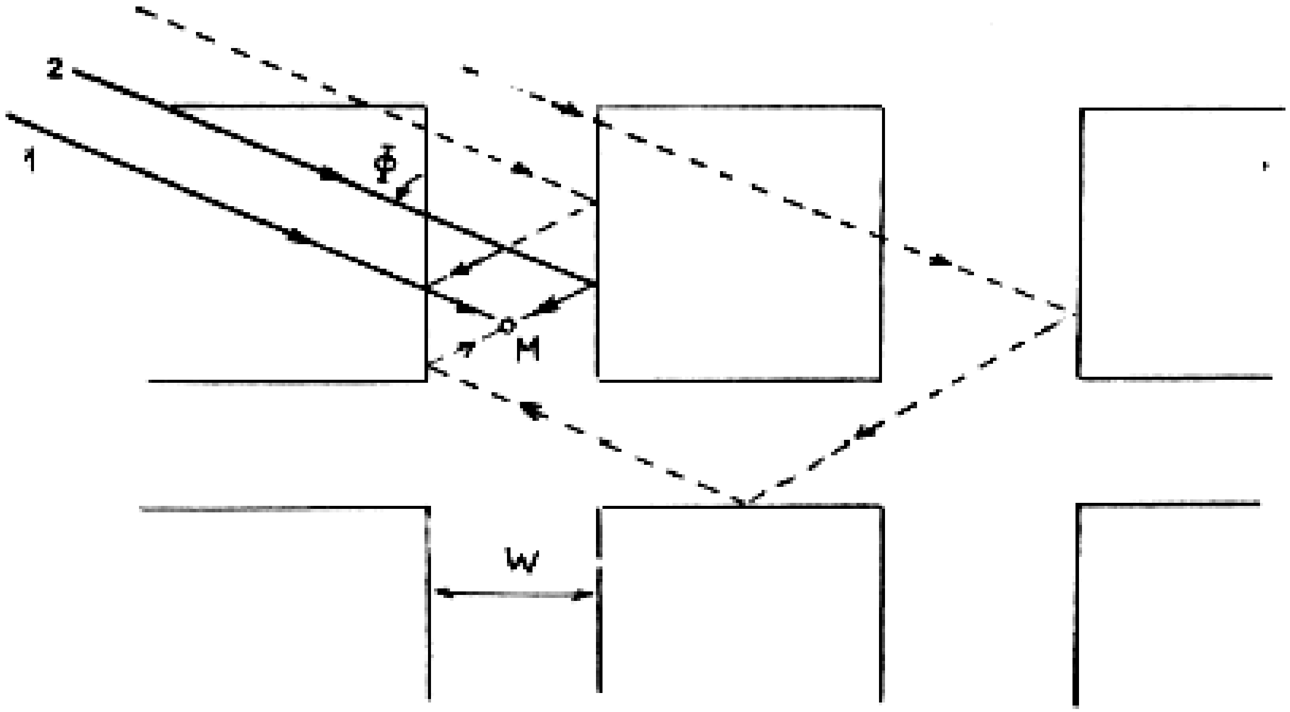
7. Macro-cells

7.2 Multipath effect



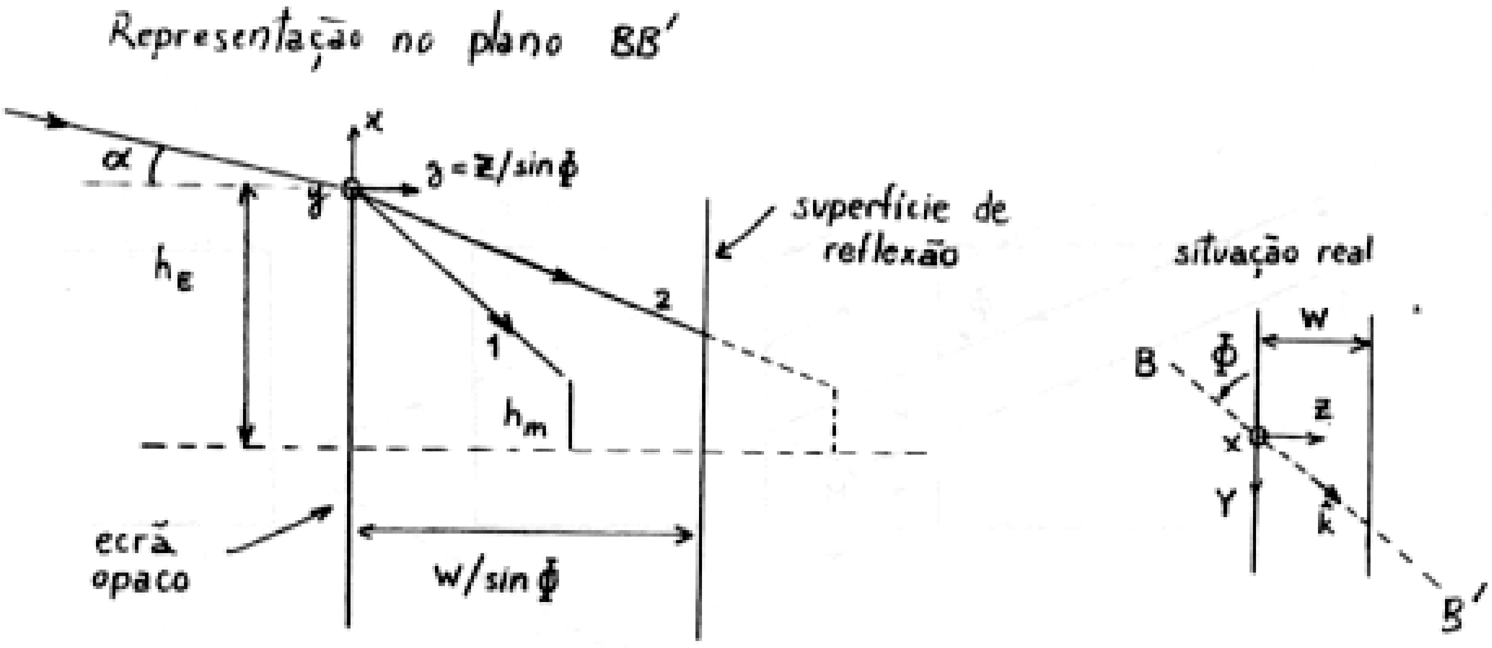
7. Macro-cells

7.2 Multipath effect



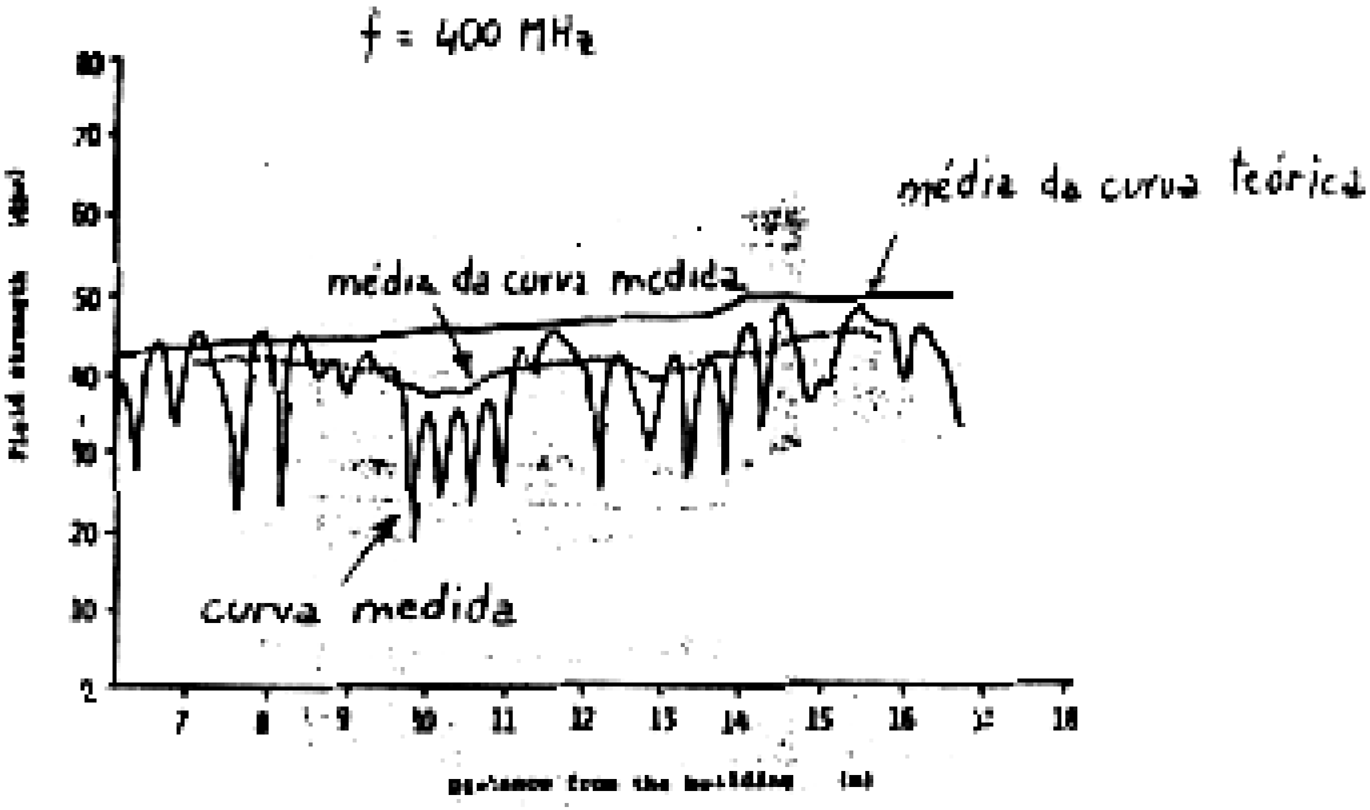
7. Macro-cells

7.2 Multipath effect



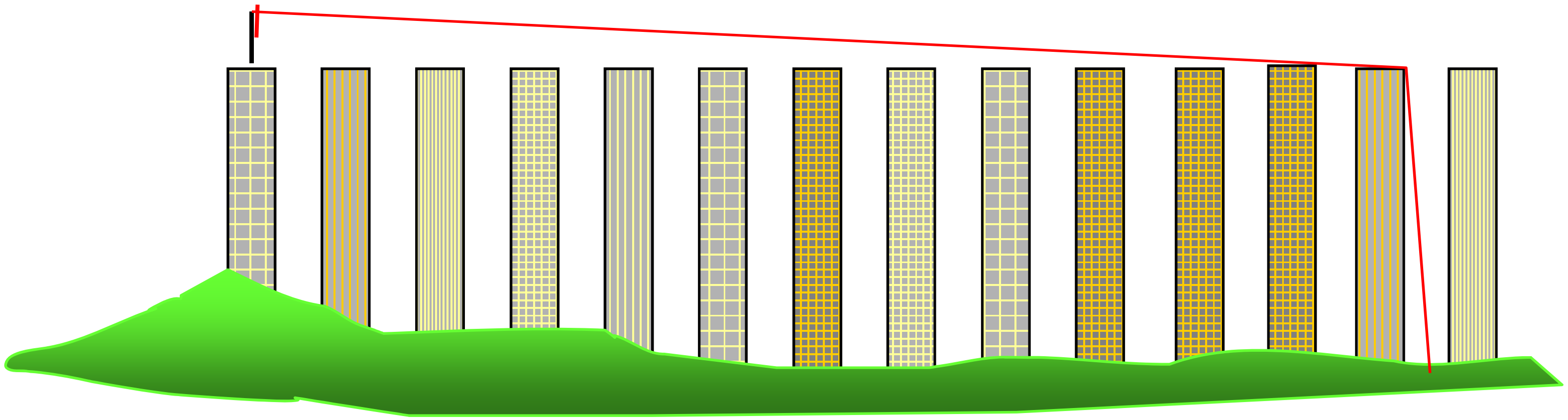
7. Macro-cells

7.2 Multipath effect



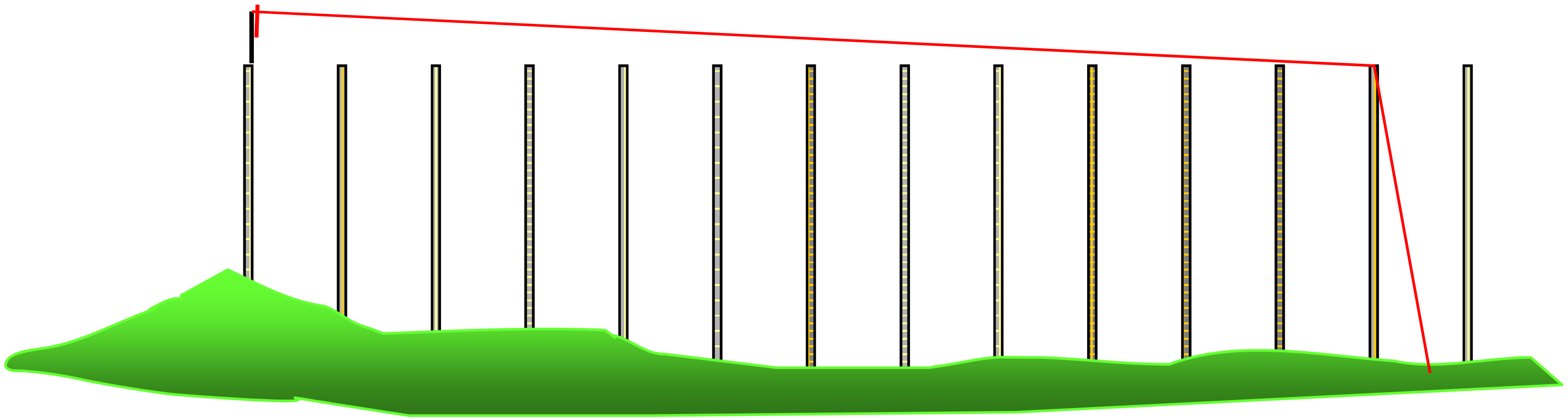
7. Macro-cells

7.3 Shadowing effect



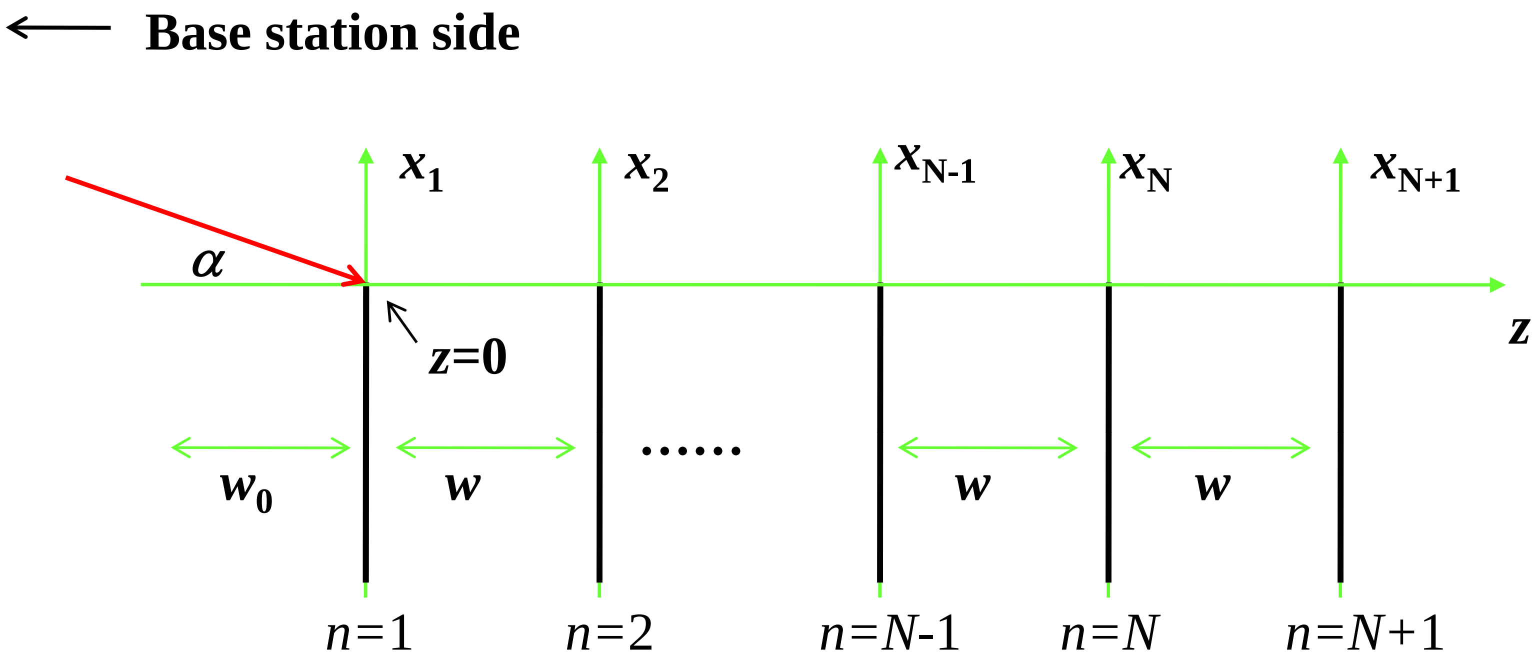
7. Macro-cells

7.3 Staggered knife-edge obstacles



7. Macro-cells

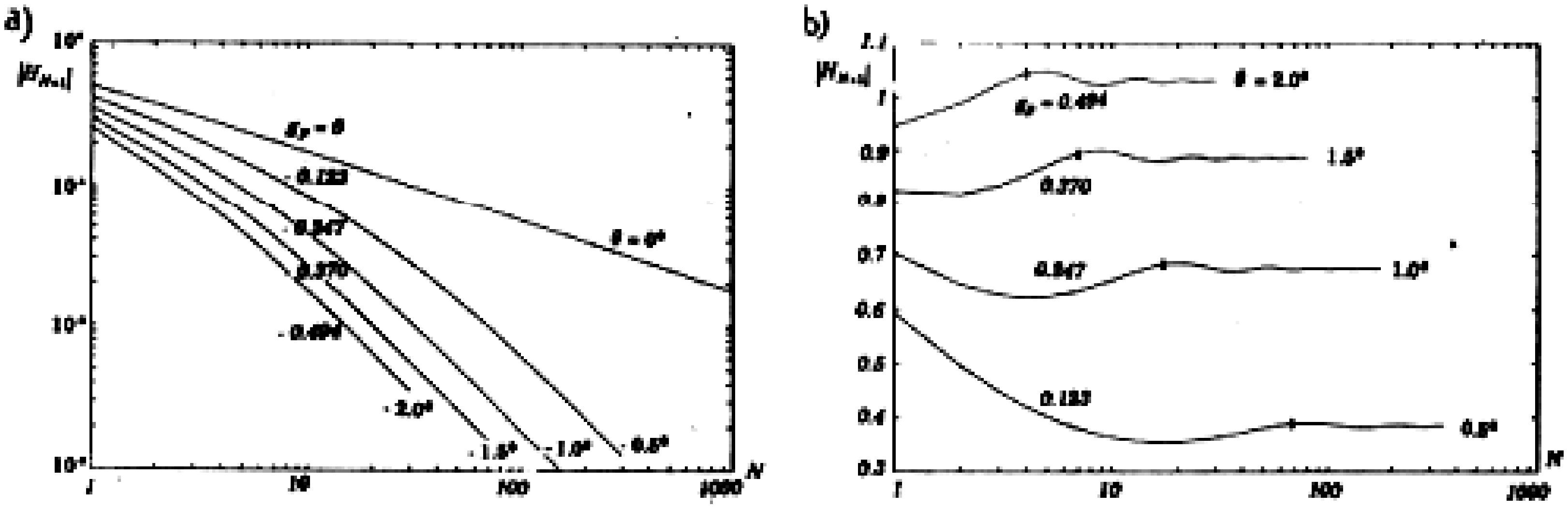
7.4 Xia and Bertoni multi-obstacle attenuation model



7. Macro-cells

7.4 Xia and Bertoni multi-obstacle attenuation model

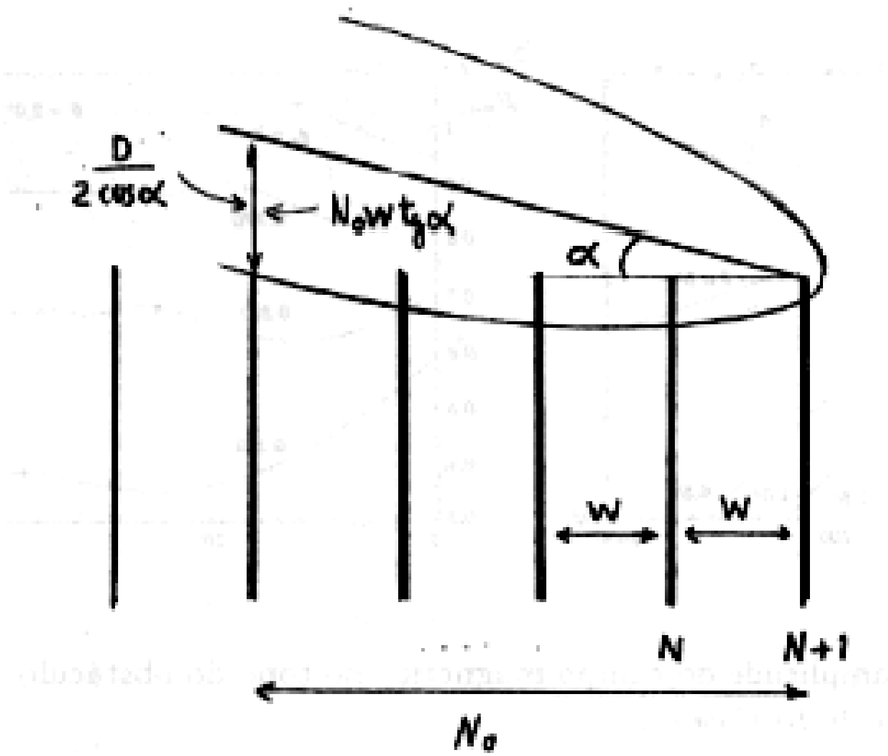
Attenuation function vs number of obstacles



7. Macro-cells

7.4 Xia and Bertoni multi-obstacle attenuation model

Interpretation of attenuation settling behaviour



7. Macro-cells

7.4 Xia and Bertoni multi-obstacle attenuation model

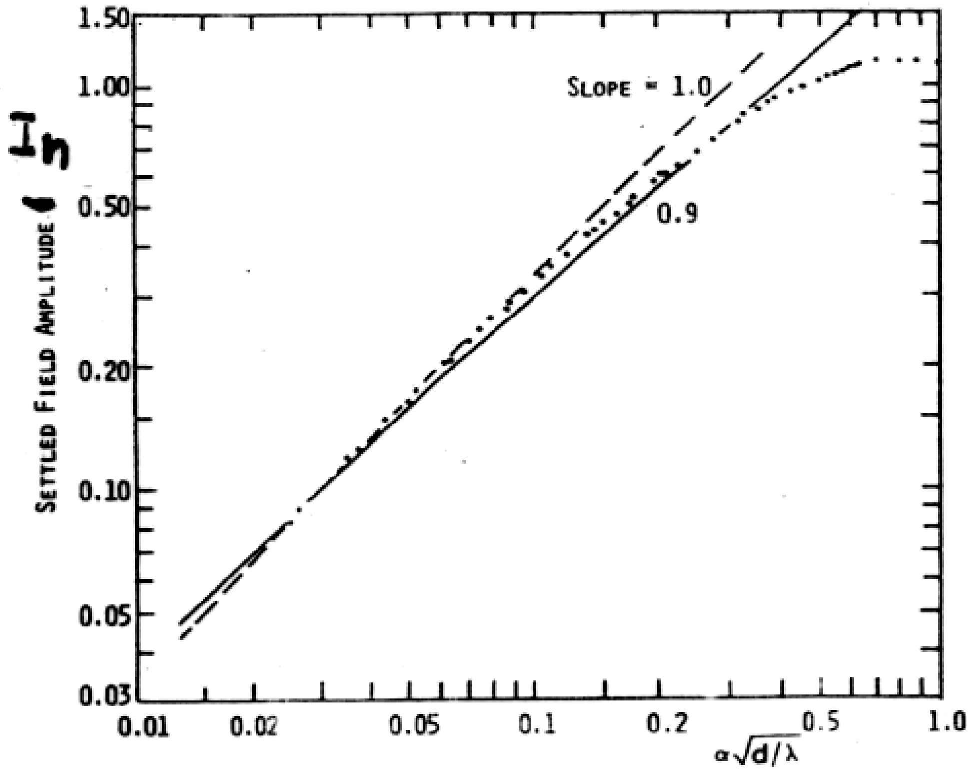
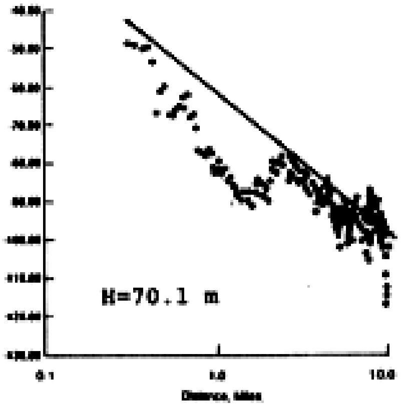


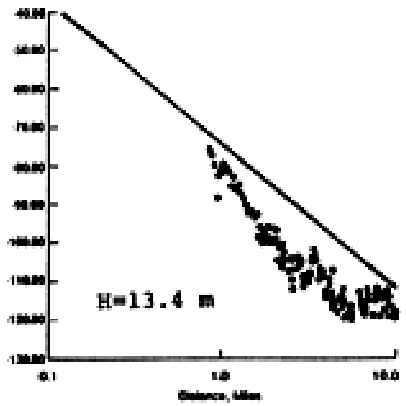
Fig. 5. Dependence of the settled field Q on the parameter $\alpha\sqrt{d/\lambda}$ with α in radians. Solid line has slope 0.9, dashed line has slope 1.0.

7. Macro-cells

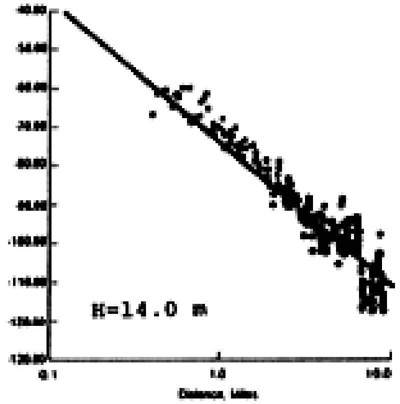
7.4 Xia and Bertoni multi-obstacle attenuation model



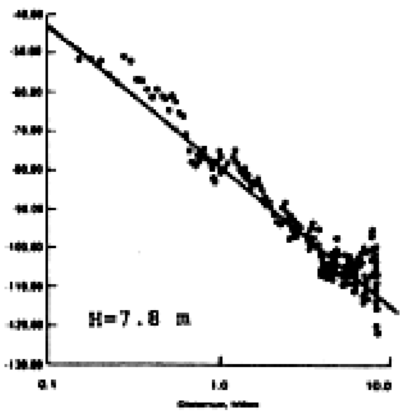
Location 1, Arch.



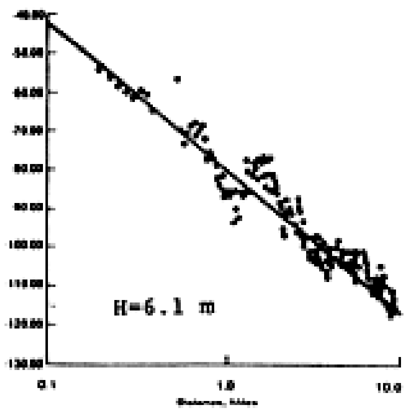
Location 2, Pennypacker - High.



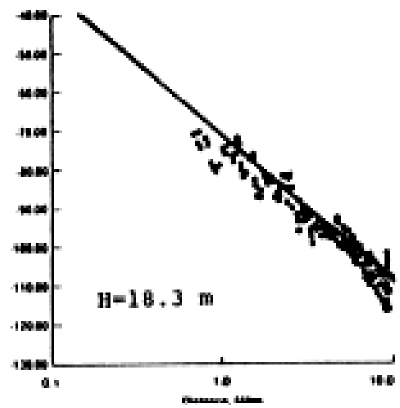
Location 3, Dewey.



Location 4, Saratoga.



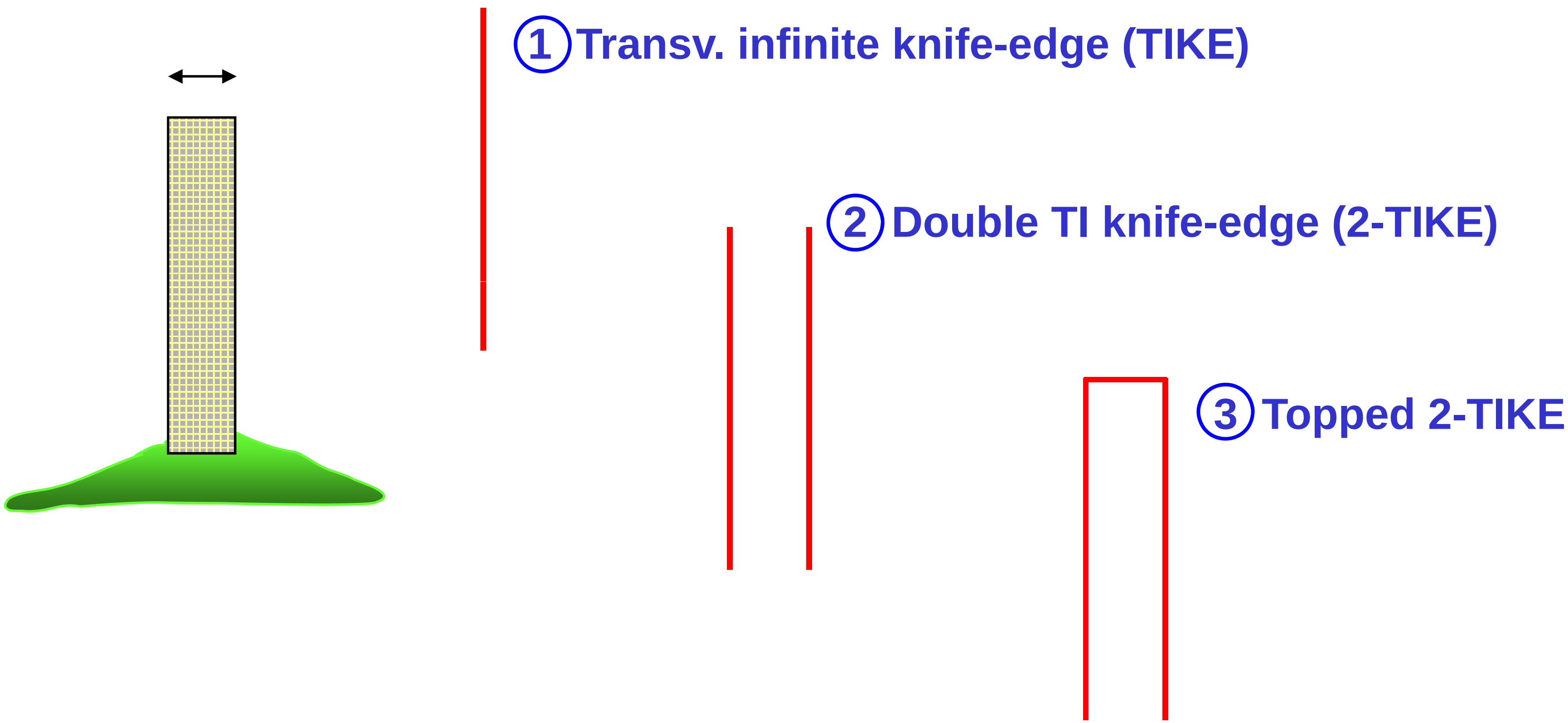
Location 5, Ivy Ridge.



Location 6, Jefferson.

8. Advanced obstacle characterization

8.1 Finite depth of obstacle



8. Advanced obstacle characterization

8.1 Finite depth of obstacle

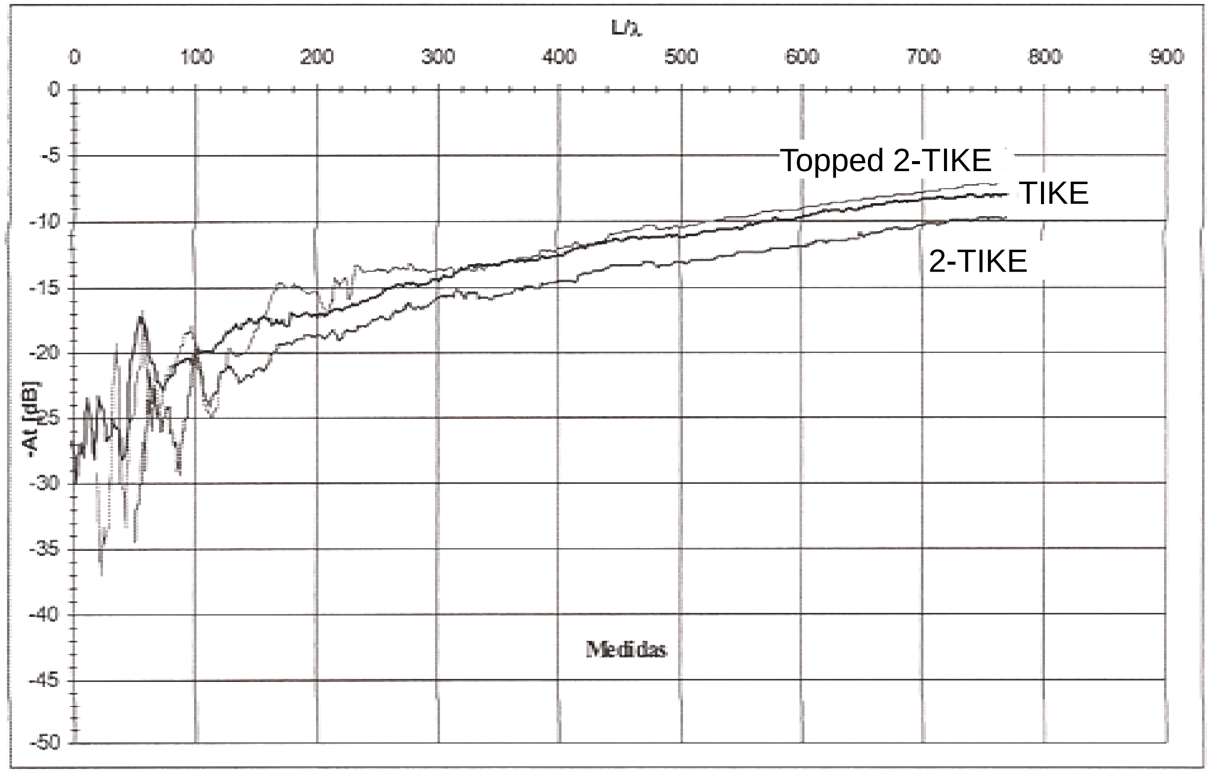
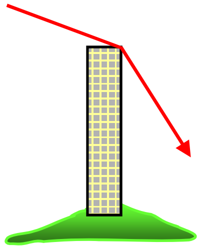


Figura 3.37 - Comparação dos valores experimentais obtidos para os vários tipos de obstáculos com a corneta piramidal como antena do móvel ($\hat{h}_0 = 350.7$)



$$\frac{x_e}{\lambda} = 8.9$$

$$\frac{x_r}{\lambda} = 37.3$$

$$\frac{d_e}{\lambda} = 137.3$$

8. Advanced obstacle characterization

8.1 Finite depth of obstacle

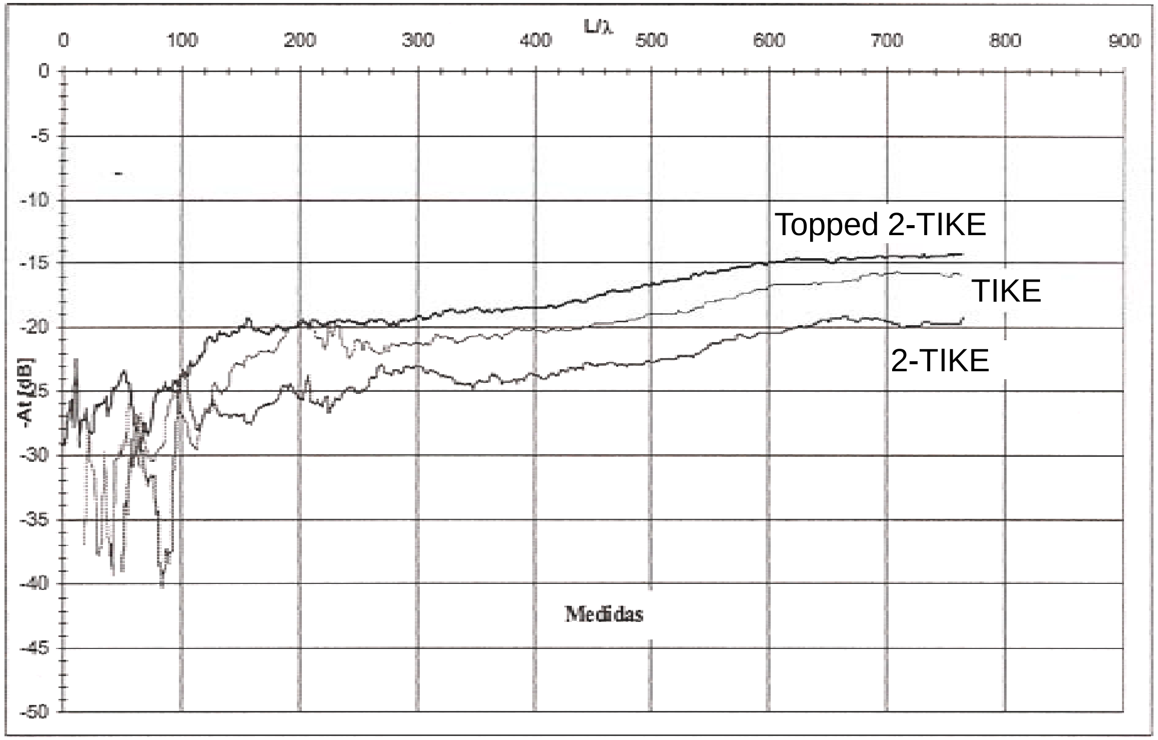
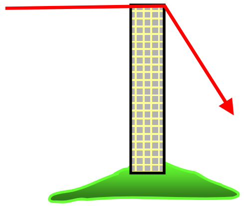


Figura 3.38 - Comparação dos valores experimentais obtidos para os vários tipos de obstáculos com a corneta piramidal como antena do móvel ($\hat{h}_0 = 341.7$)



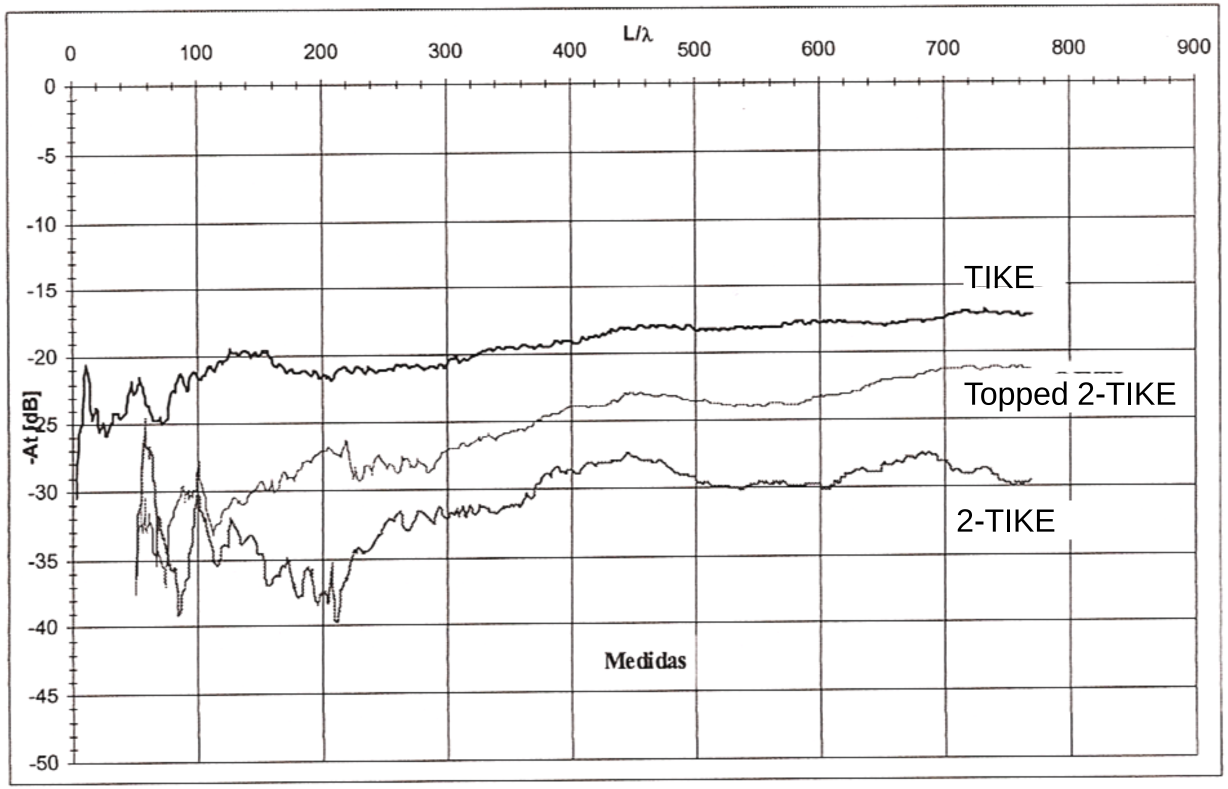
$$\frac{x_e}{\lambda} = 0$$

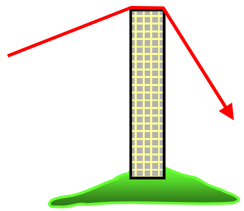
$$\frac{x_r}{\lambda} = 37.3$$

$$\frac{d_e}{\lambda} = 137.3$$

8. Advanced obstacle characterization

8.1 Finite depth of obstacle





$$\frac{x_e}{\lambda} = -9.0$$

$$\frac{x_r}{\lambda} = 37.3$$

$$\frac{d_e}{\lambda} = 137.3$$

8. Advanced obstacle characterization

8.2 Finite width obstacle

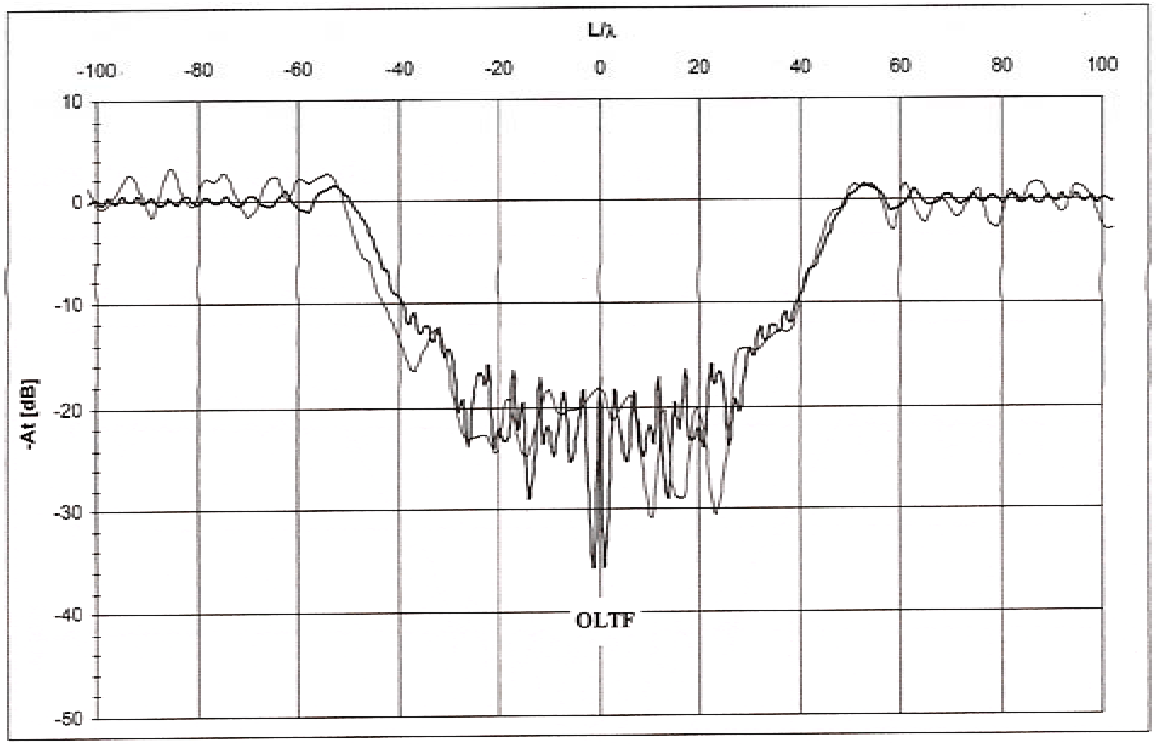
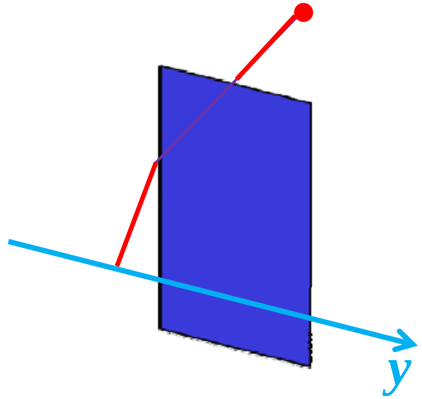


Figura 3.16 - Resultados experimentais e teóricos da atenuação suplementar introduzida por um OLTF em função do deslocamento transversal do móvel. ($\hat{x}_0 = -0.8$, $\hat{a}_1 = 88.1$)



$$\frac{x_e}{\lambda} =$$

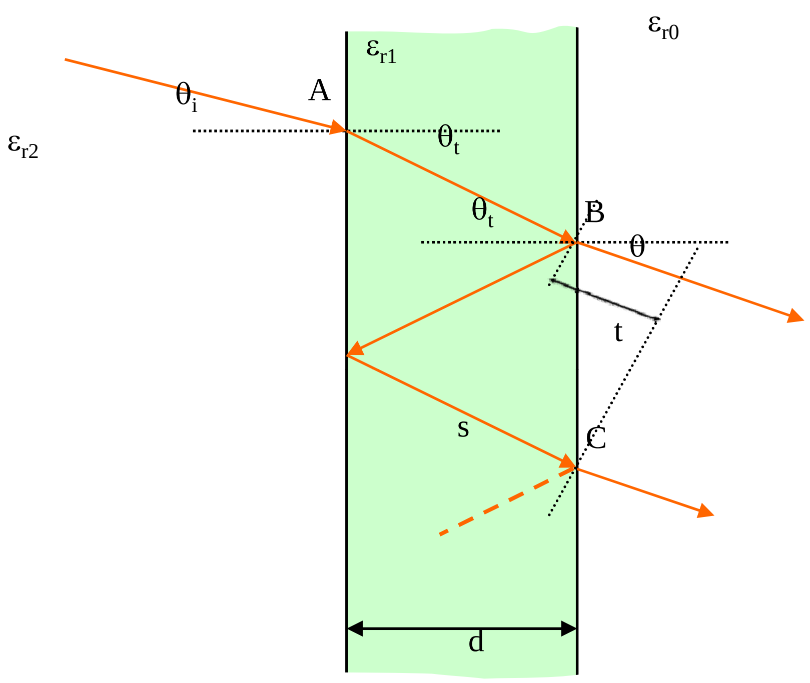
$$\frac{x_r}{\lambda} =$$

$$\frac{d_e}{\lambda} =$$

8. Advanced obstacle characterization

8.3 Through-the-wall attenuation

Generalized transmission coefficient



$$T_g = \frac{E_t}{E_i} = \frac{T_{21}\,T_{10}\,e^{-j k_0 n_1 s}}{1-\Gamma_{10}\,\Gamma_{12}\,e^{-j2k_0 n_1 s}e^{jk_0 t}}$$

$$T_{21} = \frac{2\,n_{21}\cos\theta_i}{\cos\theta_i + n_{21}\cos\theta_t} \qquad T_{10} = \frac{2\,n_{10}\cos\theta_t}{\cos\theta_t + n_{10}\cos\theta}$$

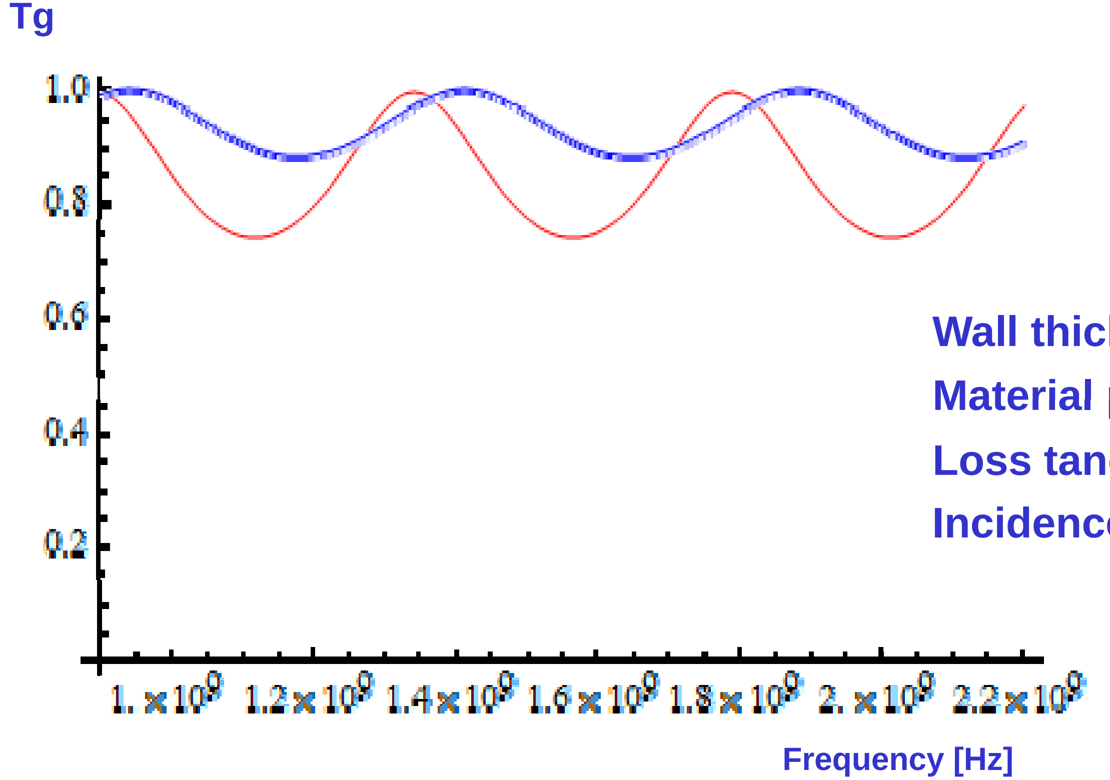
$$\Gamma_{10} = \frac{\cos\theta_t - n_{10}\cos\theta}{\cos\theta_t + n_{10}\cos\theta} \qquad \Gamma_{12} = \frac{n_{21}\cos\theta_t - \cos\theta_i}{n_{21}\cos\theta_t + \cos\theta_i}$$

$$n_{21} = \frac{\sqrt{\varepsilon_{r2}}}{\sqrt{\varepsilon_{r1}}} = \frac{1}{n_{12}} \qquad n_{10} = \frac{\sqrt{\varepsilon_{r1}}}{\sqrt{\varepsilon_{r0}}} = \sqrt{\varepsilon_{r1}} = n_1$$

8. Advanced obstacle characterization

8.3 Through-the-wall attenuation

Generalized transmission coefficient (parallel polarization)



Wall thickness *d*: 15 cm

Material permittivity: 5

Loss tangent: 0

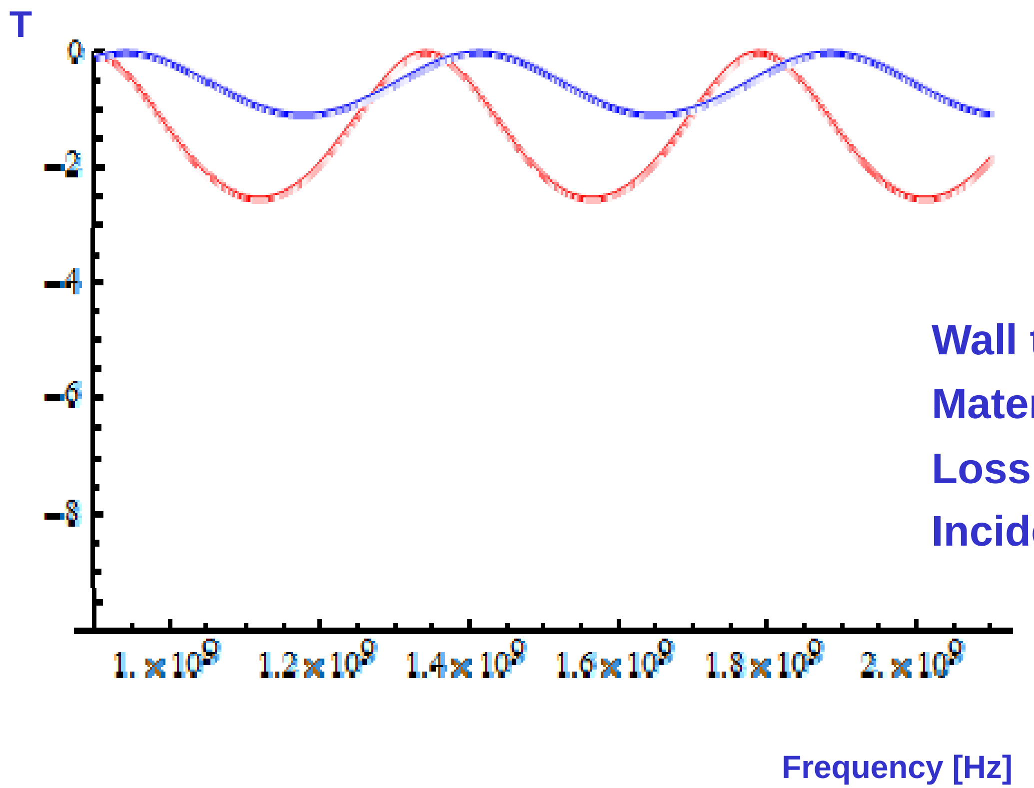
Incidence angle: 0 ——

45º ——

8. Advanced obstacle characterization

8.3 Through-the-wall attenuation

Transmissivity from generalized transmission coefficient (parallel polarization)



$$T = \frac{S_t \cos\theta}{S_i \cos\theta_i} = \left|T_g\right|^2 \frac{\cos\theta}{n_2 \cos\theta_i}$$

Wall thickness *d*: 15 cm

Material permittivity: 5

Loss tangent: 0

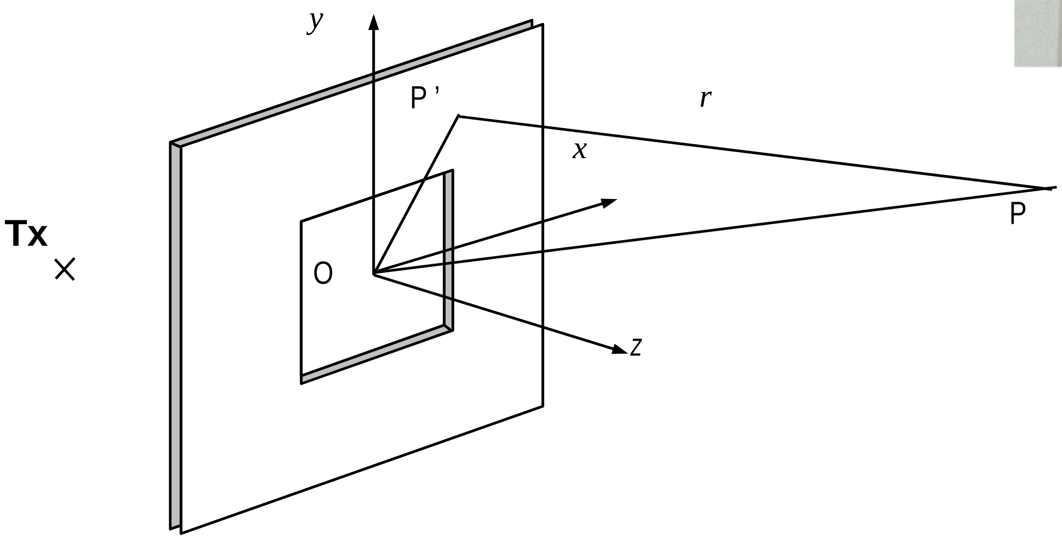
Incidence angle: 0 —

45º —

8. Advanced obstacle characterization

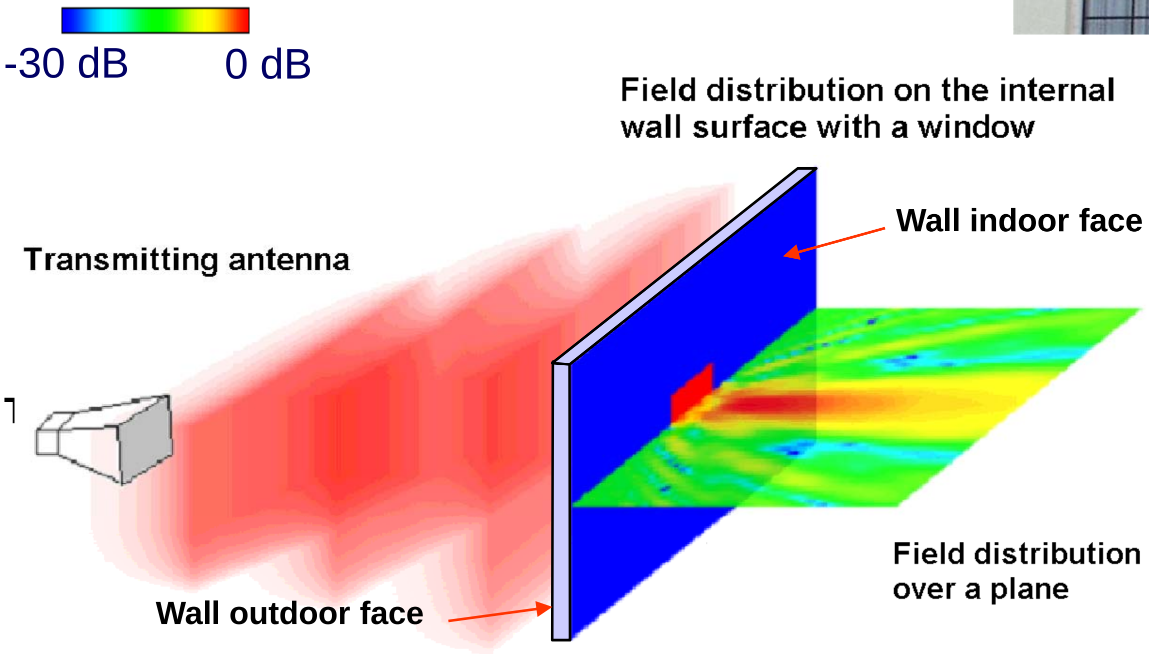
8.4 Wall with openings (windows or doors)

- Windows enhance through-the-wall transmission
- Need to quantify the influence of window size in wall transmission loss;



8. Advanced obstacle characterization

8.4 Wall with openings (windows or doors)

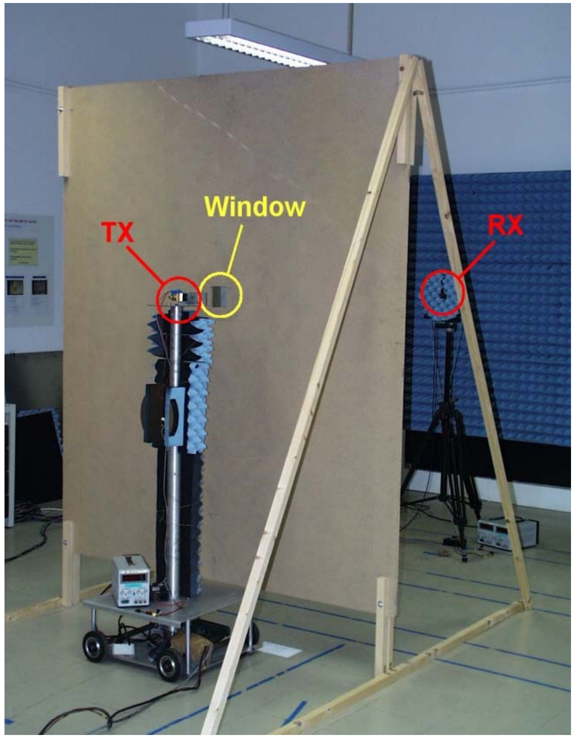


Rui Alegre; Jorge Silva – Prémio Luis Vidigal

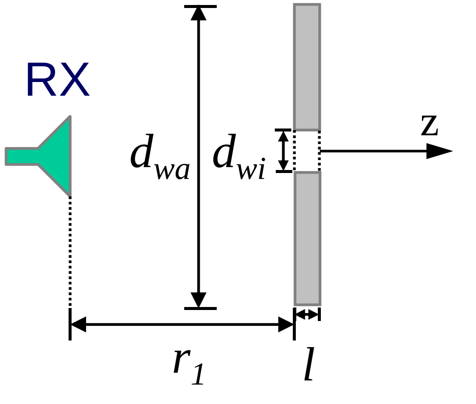
8. Advanced obstacle characterization

8.4 Wall with openings (windows or doors)

Scaled experiment for 43.0 GHz.

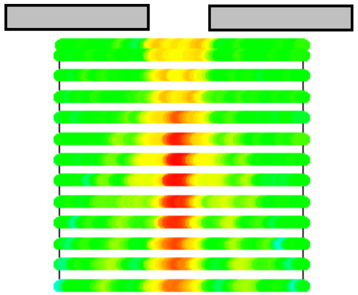
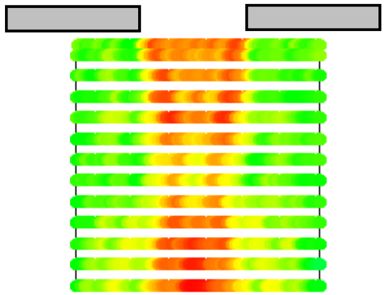
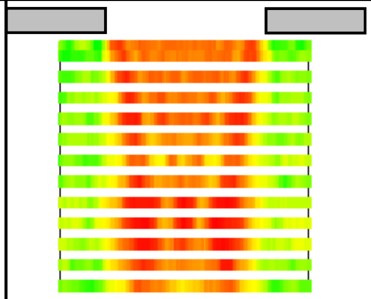
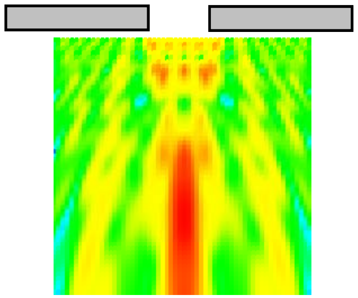
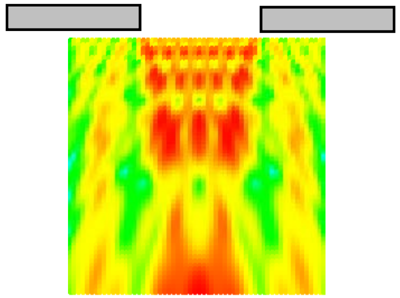
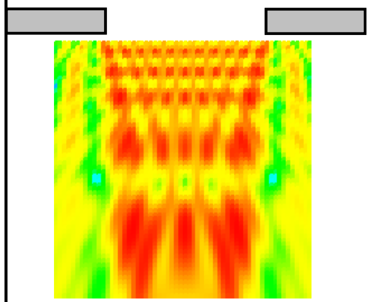


	Experimental	Simulation
f [GHz]	43.0	1.8
l [cm]	1.7	40.6
r_1 [m]	2.1	50.2
A_{wa} [m^2]	2.4×1.7	3.0×3.0
A_{ro} [m^2]	0.124×0.124	3.0×3.0



8. Advanced obstacle characterization

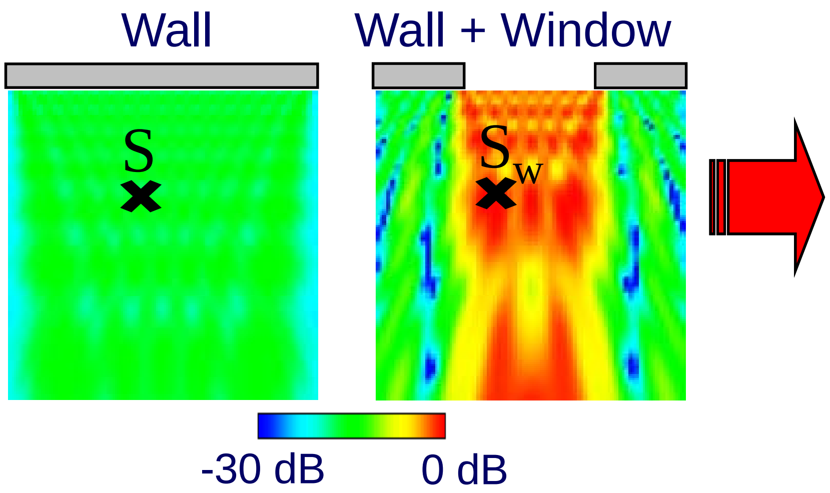
8.4 Wall with openings (windows or doors)

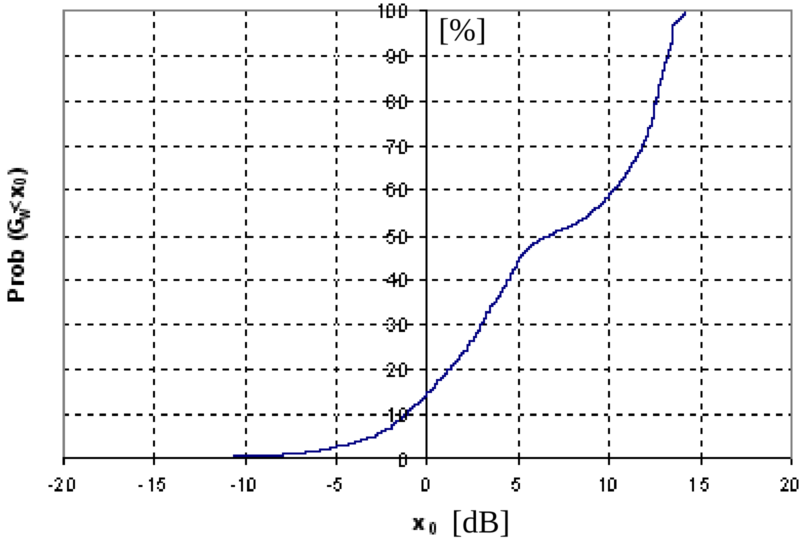
d_w [m]	0.0423	0.063	0.0887
Experimental (scaled model 43 GHz)			
Simulations			
d_w [m]	1.01	1.5	2.12

8. Advanced obstacle characterization

8.4 Wall with openings (windows or doors)

Definition of “Window Gain”: $G_w[dB] = 10\log(S_w/S)$





Cumulative distribution function of G_w

8. Advanced obstacle characterization

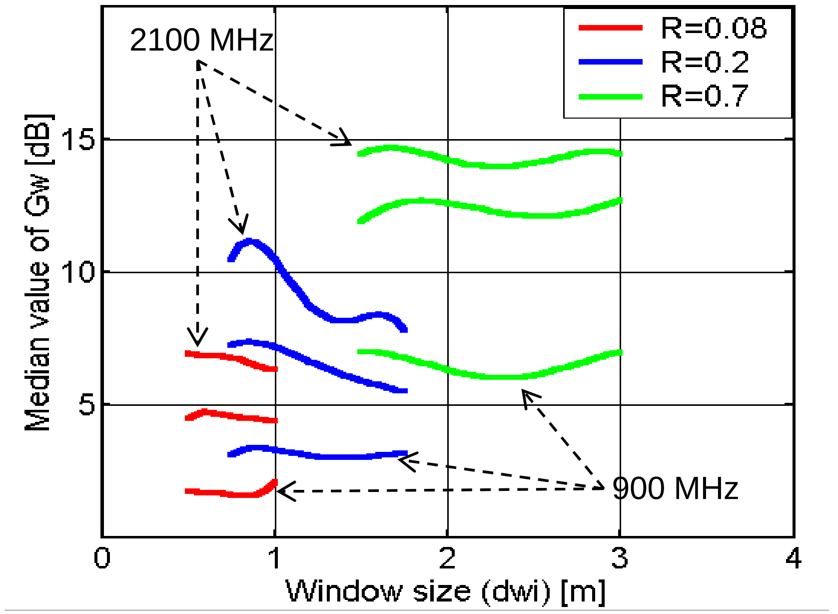
8.4 Wall with openings (windows or doors)

G_w behaviour (concrete wall)

$$R = \frac{A_{wi}}{A_{wa}}$$

(window area)

(wall area)



- Increasing the window size with constant R leads nearly to constant Gw (dependence only with R and f)
- G_w increases with R (at constant frequency)
- G_w increases with frequency (at constant R)